GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT INITIATION

Date: April 26, 1977

Project Title: "Controlled Landfill Stabilization by Leachate Recycle"

Project No: E-20-614 (Continuation of E-20-677)

Project Director: Dr. F. G. Pohland

Sponsor: Environmental Protection Agency

Agreement Period: From 3/1/77 Until ~~2/25/78~~ Dec 31/79 ~~10/31/79~~ ~~31 March 79~~

Type Agreement: Grant No. R803953020

Amount: $25,000 EPA
4,600 GIT (E-20-346)
$29,600 Total

Reports Required: Quarterly Progress Reports, Final Report

Sponsor Contact Person (s):

Technical Matters

Dr. D. R. Brunner
Municipal Environmental Research Laboratory
Environmental Protection Agency
Cincinnati, Ohio 45268

Contractual Matters
(thru OCA)

Frederick L. Meadows
Chief, Grants Operations Branch
Grants Administration Division
Environmental Protection Agency
Washington, D. C. 20460

Defense Priority Rating: none

Assigned to: Civil Engineering (School/Laboratory)

COPIES TO:

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- Other

CA—3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 7/6/83

Project Title: Controlled Landfill Stabilization by Leachate Recycle

Project No: E-20-614

Project Director: F. G. Pohland

Sponsor: Environmental Protection Agency

Effective Termination Date: 12/31/79 (performance)

Clearance of Accounting Charges: 12/31/81 (reporting)

Grant/Contract Closeout Actions Remaining:

NONE

- ☐ Final Invoice and Closing Documents
- ☐ Final Fiscal Report
- ☐ Final Report of Inventions
- ☐ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other _____

Request that Dr. Pohland sent two(2) copies of Final Report to OCA Reports Coordinator(PPC). (Project Summary Report has been forwarded to PPC)

Assigned to: CE (School/~~laboratory~~)

COPIES TO:

Administrative Coordinator	Research Security Services	EES Public Relations (2)
Research Property Management	Reports Coordinator (OCA)	Computer Input
Accounting	Legal Services (OCA)	Project File
Procurement/EES Supply Services	Library	Other Pohland

FORM OCA 10:781

Quarterly Progress Report No. 7

"Controlled Landfill Stabilization by Leachate Recycle"

EPA Grant No. R-803953-02

Research Project E-20-614

Georgia Institute of Technology

March 1, 1977 - May 31, 1977

As detailed in the previous quarterly report and renewal proposal, the two simulated landfill cells have been operated and monitored with respect to internal and external environmental conditions since neither cell has yet reached field capacity. Accordingly, records on temperature, relative humidity, and precipitation have been extended to refect normal variations for the seasonal period covered by this report. Additionally, gas analysis on the closed cell have indicated no methane production in either the head space or distribution system with some detectable indication of generation of carbon dioxide within the refuse mass attributable to biological activity. However, the loss of liner integrity in the closed cell makes these analyses somewhat less than absolute.

Because complete and continuous isolation of the contents of the closed cell were considered paramount to the success of the research endeavor, much of the effort during this report period was devoted to the design, fabrication, installation and evaluation of a new seal on the closed cell. Although this activity was delayed somewhat by the delay until April of formal approval of continuation support, a 0.25-inch cold rolled steel plate, 13 feet square with a 24-inch square observation well and cover was designed and fabricated for installation at the top of the closed cell. The walls were prepared to receive the plate by applying 0.25 inches of concrete grout with a 2-inch center slot into which two strands of 0.625-inch Tygon tubing was placed after the grout had dried and the gaps between the tubing could be filled with 3M-202 sealant. The latter sealant was chosen over 3M-2084 since pressure tests indicated that it did not exhibit any pressure drop over a 48-hour period whereas the 3M-2084 tended to allow gas to escape during curing. The pressure tests on each sealant were performed in a 1.5-liter glass container with a ground glass top between which samples of sealant ($\sim$ 1.5 sq. in.) could be placed and exposed to a gas pressure equivalent to approximately 2.0 inches of water. The gas used in the tests contained over 90% methane and the temperature was maintained at 20°C.

The steel plate was supported by 4.0-inch I-beams spot-welded to 3.0-foot lengths of $\frac{1}{4}$"x3"x3" angle irons bolted to the inside of the cell walls. The intersection of the I-beams was further secured by a 1.0-foot square steel plate, 0.25-inch thick, welded to the central I-beam in support of the other shorter two cross members. Finally, the steel plate was drawn against the seal with $\frac{1}{2}$"x6" bolts placed through the plate on 6-inch centers around the periphery of the cell and secured to 3.0-inch angle irons bolted into the exterior walls. At the end of this report period, the plate had been installed and all indications suggest that the closed cell has been completely sealed again.

With the repair of the seal on the closed cell, it is anticipated that the research can proceed as initially conceived. It has been perhaps fortuitous that rainfall events during the interval for repair have been less than usual so their impact on eventual results should be reduced. In any event, until field capacity has been attained, it is unlikely that biological activity will be intensified. As leachate appears for recycle, regular analyses will be performed for leachate constituents as well as gas production and composition.

Frederick G. Pohland
Project Director

Quarterly Progress Report No. 8

"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-803953-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
June 1, 1977 - August 31, 1977

As described in the previous quarterly progress report, a new seal was placed on the closed simulated landfill cell. It consisted of a steel plate bolted and bonded to the landfill containment structure. During the initial phases of this report period, additional efforts were placed on securing the lid, painting, re-establishing sampling points, providing for automatic control and recording of recycle pumping sequences, and locating and installing an instrument shed within the security fencing surrounding the entire test site. Some delay was experienced in acquiring materials for this effort, but in terms of overall control of the research effort, this delay was considered justified.

After all systems were reinstalled in the closed cell, make-up water, equivalent to about 1200 gallons of rainfall received on the open cell was added in increments of 150 gallons every other day with the leachate recycle sump pumping system. When all make-up water had been added, the cell was allowed to stand for appoximately five days at which time the recycle sump lines of both cells were opened and the accumulated leachate (~10-15 gallons per cell) was recycled. Since this adjustment, some leachate has been observed occasionally in the open cell, particularly after heavy rainfalls. These accumulations have been measured and are being sampled now before being returned to the open cell.

Since it is estimated that the cells should be nearing field capacity having received approximately 3000 gallons of moisture, it is anticipated that leachate will begin to appear with more regularity from each test cell. Therefore, a schedule for sampling and analysis has been established to follow the behavior of the leachate constituents with the various recycle intervals. The frequency of sampling will depend upon the rate at which detectable changes in parameters occur. Preliminary leachate analyses on grab samples have indicated that the leachate from both cells exhibit characteristics associated with acid fermentation with low pH and relatively high concentrations of soluble constituents. However, since there has been

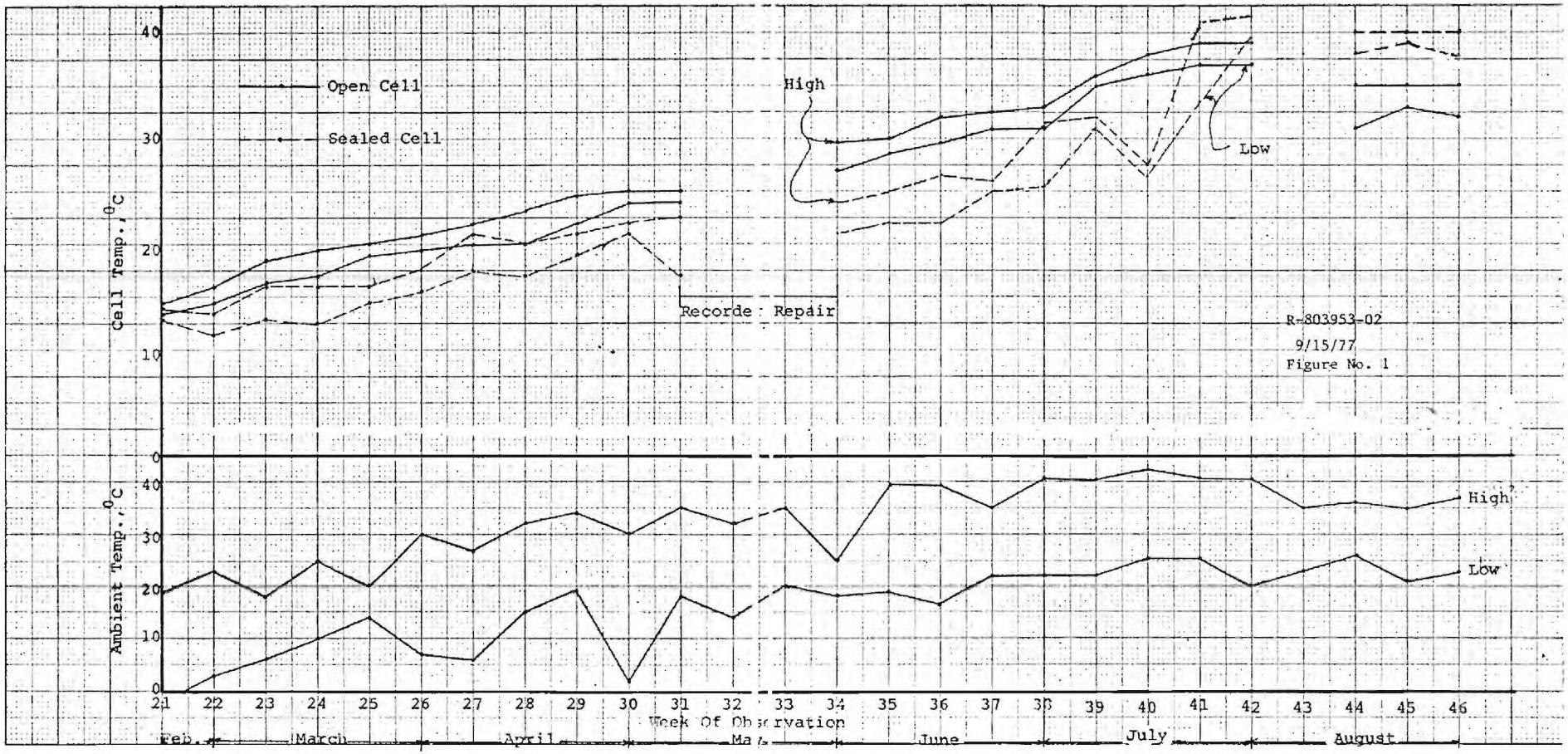
some delay in moisture contact in the closed cell and the quantity of leachate initially has been greater from the open cell, interpretive analysis of these results would be somewhat premature. Such differences should equalize now that the two systems are being operated similarly and as more moisture accumulates in the cells.

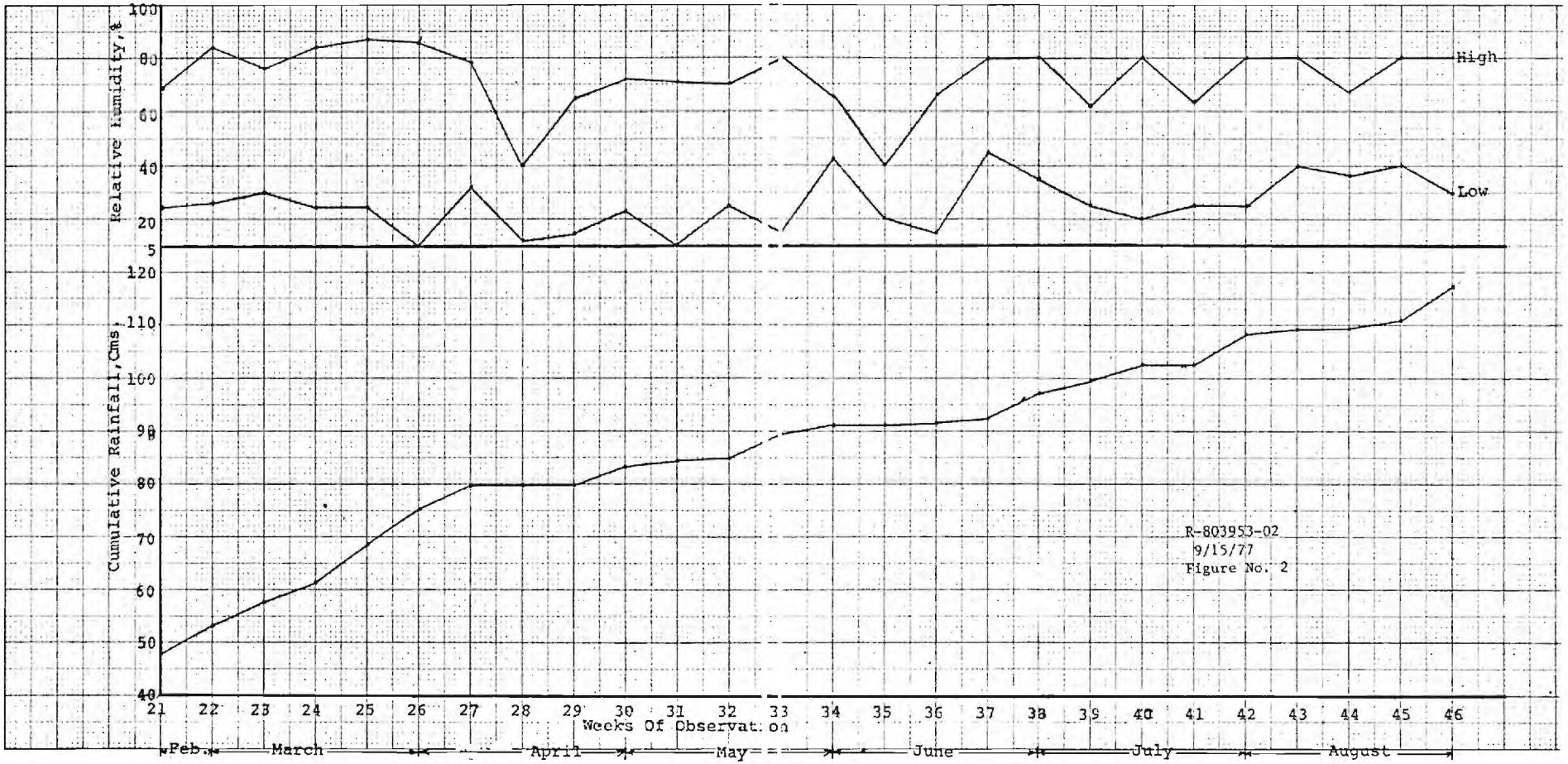
Although gas analyses have been made to check the gas composition in the head space, alternate gas collection system, and leachate distribution system of the closed cell, analyses have been influenced by the exposure of the closed cell during re-sealing and also, and probably more significantly, by the apparent vacuum created by the movement of the water through the test cell after rainfall equivalent had been added. Accordingly, when attempts were made to acquire gas samples, the negative pressure in the sampling areas of the closed cell caused some air to be drawn into the sampling system. Unfortunately, this effect has only recently been detected and may have also accounted for the smaller volume of leachate from the closed cell if the moisture has been held in the refuse mass by the negative pressures. This situation is presently being remedied during tests being conducted to determine the integrity of the seal on the closed cell although the observed negative pressures would suggest that the system is gas tight. Relief of this negative pressure either by introduction of an inert gas or by indigenous gas evolution should permit moisture transfer throughout the refuse mass more like what is occurring in the closed cell.

In spite of the interruptions experienced while the closed cell was being re-sealed, continous moinitoring of cell and ambient temperatures, relative humidity and rainfall have proceeded. Accordingly, the data indicated in Figures 1 and 2 record these parameters with time since the last reporting (Quarterly Progress Report No. 6). No unusual variations were noted in any of the parameters except that the cell temperature of the closed cell exceeded that of the open cell after the new lid was installed. Since this installation occurred during a very high temperature period, some of the heat was probably trapped within the closed cell after sealing. It is also possible that some incipient heat evolution occurred when the cell was closed and make-up water was added. Without reliable confirmatory gas analyses, this latter possibility is difficult to determine. However, more recent data indicate that the temperature within the closed cell is remaining about 4°C higher than the open cell.

Total cumulative rainfall through the report period is approaching 120 cm or about 2900 gallons (~11,000 liters) which should not yet be sufficient to bring either cell to field capacity. Therefore, what leachate has been observed is probably due to some shortcircuiting which seems to appear only after heavy rainfall and only to a measurable degree in the open cell. Normally the quantity is small and is returned to the respective cells after each event. Area rainfall has been less than normal by about 25 cm during this report period. It is anticipated that moisture accumulation within the cells will accelerate during the next report period when the fall rains begin.

Frederick G. Pohland
Project Director


Open Cell
Sealed Cell
High
Low
Recorde - Repair
R-803953-02
9/15/77
Figure No. 1
Cell Temp., °C
Ambient Temp., °C
High
Low
Week Of Observation
Feb.
March
April
May
June
July
August


Relative Humidity, %
100
80
60
40
20
5
High
Low
Cumulative Rainfall, Cms.
120
110
100
90
80
70
60
50
40
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
Weeks Of Observation
Feb.
March
April
May
June
July
August
R-803953-02
9/15/77
Figure No. 2

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
IVIL ENGINEERING

TELEPHONE:
(404) 894-2265

December 8, 1977

Mr. Dirk Brunner, Project Manager
Municipal Environmental Research Laboratory
Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Enclosed are five copies of our ninth quarterly progress report on project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period September 1, 1977 - through November 30, 1977. I have included cumulative data on temperature, relative humidity and rainfall and although we did receive considerable precipitation in late October and early November, we have not yet reached field capacity in either cell. However, some short circuiting during heavy rainfall did permit collection and analysis of leachate; gas analyses remain uncertain with no methane being detected as yet in either unit. With the arrival of colder weather, we are adding additional insulation to safeguard against a reoccurrence of last year's freezing problems.

I enjoyed our brief meeting recently and in line with our discussions, I am proceeding to renovate the test columns used in our previous work. I have also received the application forms for preparing a new research proposal on the fate of heavy metals in landfills which I intend to complete within the next month or so. I trust our request for continuation of the current research work is acceptable and that we will receive favorable notification soon.

Best regards.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

Enclosures
FGP:jp
cc: J. E. Fitzgerald
Phyllis Oliver

Quarterly Progress Report No. 9

"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-803953-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
September 1, 1977 - November 30, 1977

During this report period, monitoring of the test cells has continued with respect to internal and external environmental conditions. Changes in temperature, relative humidity and cumulative rainfall have been recorded as indicated in the accompanying figures. No unusual events occurred during the period of observation with the exception of higher than normal precipitation during late October and early November. The temperature has also decreased with the closed cell maintaining a consistently higher value probably due to the insulation provided by the cover. Whether some heat is being generated internally is uncertain although recent gas analyses have indicated that some oxygen remains within the refuse mass in both cells. As the cells reach field capacity, this oxygen should disappear and more rapid stabilization should commence.

With the onset of colder weather, additional insulation is being placed around exposed piping or areas where freezing temperatures may damage the integrity of the liner. This action will be supplemented with pressure testing of the closed cell and installing additional protection against possible leaks as may be required. This procedure should eliminate a recurrence of problems encountered during the past winter period.

Although field capacity has not yet been reached in either cell, some leachate has accumulated particularly in the open cell after heavy rainfall. This has permitted some preliminary chemical analyses which have yielded an indication of the range of strength of leachates in each cell. These

data are presented in Table 1; no specific or comparative interpretation of these data is suggested at this time since the concentrations indicated are influenced by the quantity of leachate accumulating at the time of sampling which was always greater in the open cell than in the closed cell. However, the data do indicate that materials are being leached from the refuse and that acid production has commenced. There has been a recent trend toward similarity in constituent concentrations of the leachate from each cell but again, there will be expected difference until a routine leachate recycle schedule can be initiated.

Table 2 presents preliminary data on gas samples removed from the test cells. In the case of the open cell, gas samples were removed from only the pipe reaching into the refuse mass whereas with the closed cell samples were obtained from the head space, leachate recycle distribution system and internally from the alternate gas collection grid. As with the leachate samples, the ranges indicated are subject to problems with acquiring a truly representative gas sample during the period when field capacity had not yet been reached. Oxygen is still available in both cells and since methane has not been detected routinely, the carbon dioxide probably originates mainly from oxidative processes of decomposition. Since no measurable gas production has been recorded in the closed cell and considerable organic matter still remains in the leachate, these processes probably have not yet become significant. Initiation of routine recycle will eliminate residual oxygen and should accelerate stabilization with concomitant gas production.

In anticipation of additional time being required to reach field capacity before a routine recycle schedule can be initiated, a 12-month

extension of the current project has been requested. This extension will permit continued evaluation of leachate and gas production trends and ultimate realization of the project objectives.

Frederick G. Pohland
Project Director

Table 1

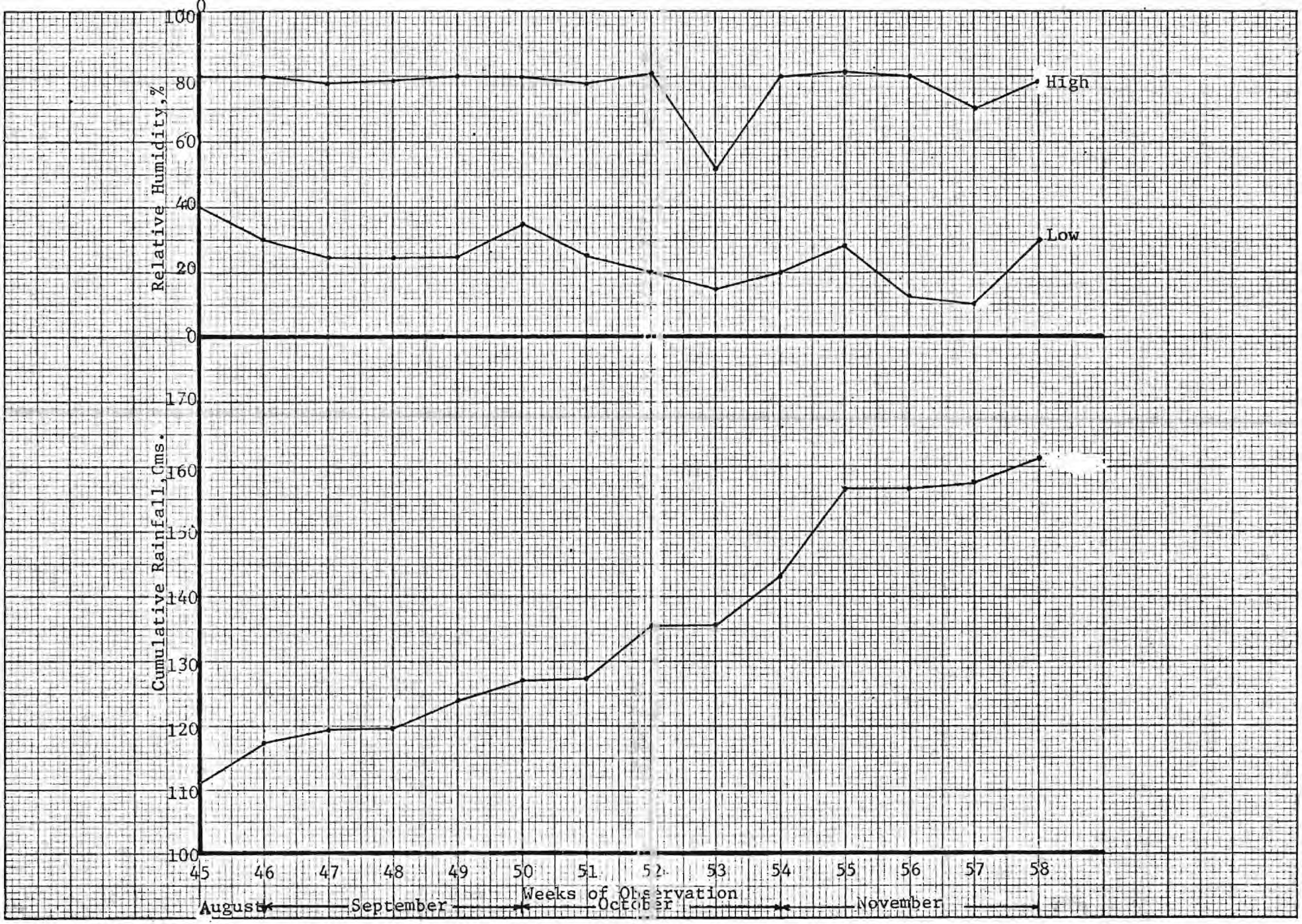
Preliminary Analyses on Leachate Samples from the Test Cells before Field Capacity Had Been Reached

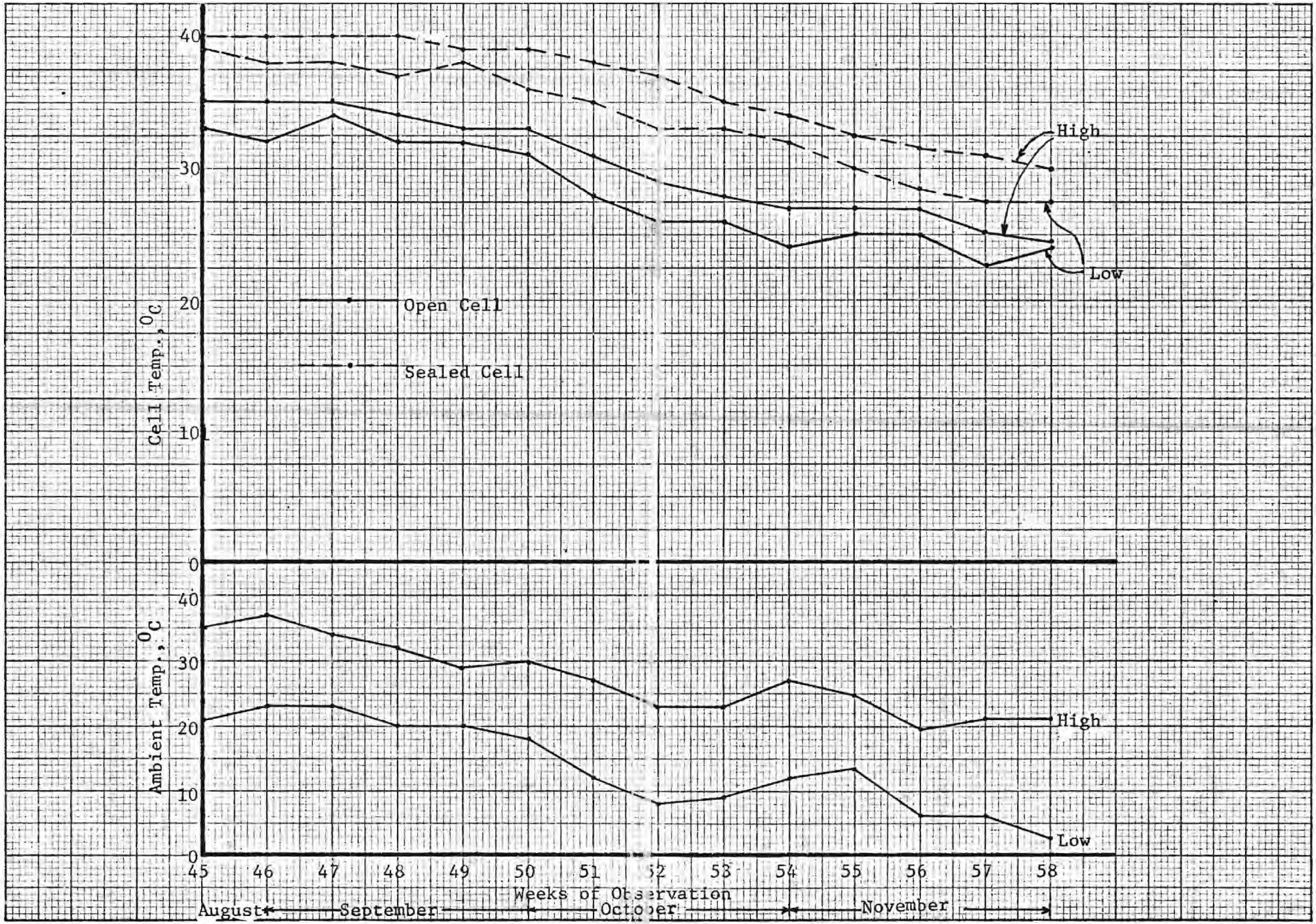
Analysis	Open Cell	Closed Cell
pH	4.85-5.4	4.9-5.35
Total Alkalinity, mg/l $CaCO_3$	2285-8187	1142-2285
Volatile Acids, mg/l		
Acetic	3600-11,600	3000-7100
Propionic	2200-7000	950-3300
Butyric	2350-10,500	820-3530
Chemical Oxygen Demand, mg/l		
Soluble	20,295-66,430	5,610-26,565
Total	20,409-66,803	6,211-29,412
Total Carbon, mg/l	8,385-26,222	2,780-40,296
Total Organic Carbon, mg/l	8,227-26,024	2,400-40,142
Total Kjeldahl Nitrogen, mg/l	960-2420	340-600
Total Solids, mg/l	20,554-51,340	6,600-24,532
Total Volatile Solids, mg/l	11,614-30,867	5,877-13,381
Suspended Solids, mg/l	28.7-293	61.3-157.1
Volatile Suspended Solids, mg/l	14.3-172	40.8-94.5
Chlorides, mg/l	933-4070	59-2237

Table 2

Preliminary Analyses on Gas Composition in Samples Removed from the Test Cells before Field Capacity Had Been Reached

Cell Identity	Sampling Position	Gas Composition, %			
		CO_2	O_2	N_2	CH_4
Open	Internal	0-23.7	12.3-21.9	60.5-85.6	0-1.7
Closed	Distribution System	0-13.8	8.4-21.7	72.9-82.0	0
	Internal	0-19.3	7.9-17.5	62.0-80.5	0-4.9
	Head Space	0-10.7	9.1-19.8	75.4-87.3	0





GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 894-2265

March 10, 1978

Mr. Dirk Brunner, Project Manager
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Enclosed are five copies of our tenth quarterly progress report on project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period December 1, 1977 to February 28, 1978. I have again included cumulative data on temperature, relative humidity and rainfall. In addition, we have reached field capacity in both units and with the onset of warmer weather, we are now preparing for continuous leachate recycle in both units.

We have received the gas detector and official approval of our continuation request. We appreciate your efforts on our behalf. I am also preparing the proposal for expansion of our studies to an investigation of the fate of heavy metals in landfills per our discussion. You should receive a pre-proposal shortly; we have proceeded to arrange to have the old columns refurbished so that we may shorten the delay time before project initiation. I missed the San Antonio solid waste conference due to a prior commitment, but my associate here attended and spoke briefly with Norb Schomaker about our research interests. I notice your name on the participants list for Halifax in April; perhaps I will see you there if not before.

Best regards.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

Enclosures
FGP:jp
cc: J. E. Fitzgerald
Phyllis Oliver

xc: AHB, 2 cys

Quarterly Progress Report No. 10

"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-803953-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
December 1, 1977-February 28, 1978

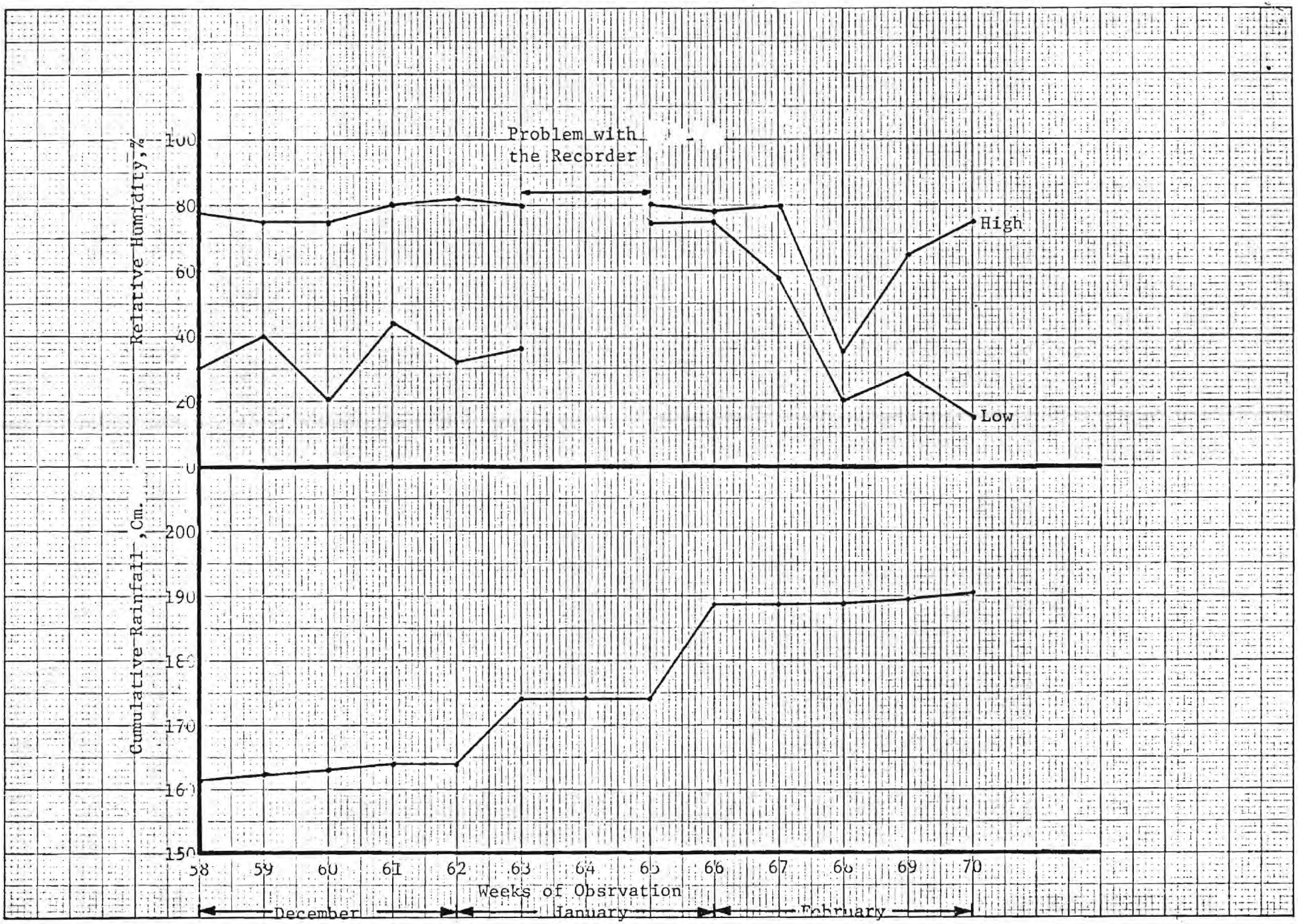
During this report period, monitoring of the internal and external environmental conditions associated with the test landfill cells continued. Changes in temperature, relative humidity and cumulative rainfall have been recorded as indicated in the accompanying figures. Although some problem with the recording systems were encountered, the results were consistent with the weather conditions at this time of year. The freezing temperatures recorded in January and February did cause some freezing problems away from the temperature probes which delayed the determination of whether field capacity had been reached as well as some uncertainties concerning the integrity of the cells and piping systems. Recent thaws have resulted in some minor leaking and the release of liquid from the bulk refuse has now led to a confirmation of moisture accumulations in excess of field capacity in both units.

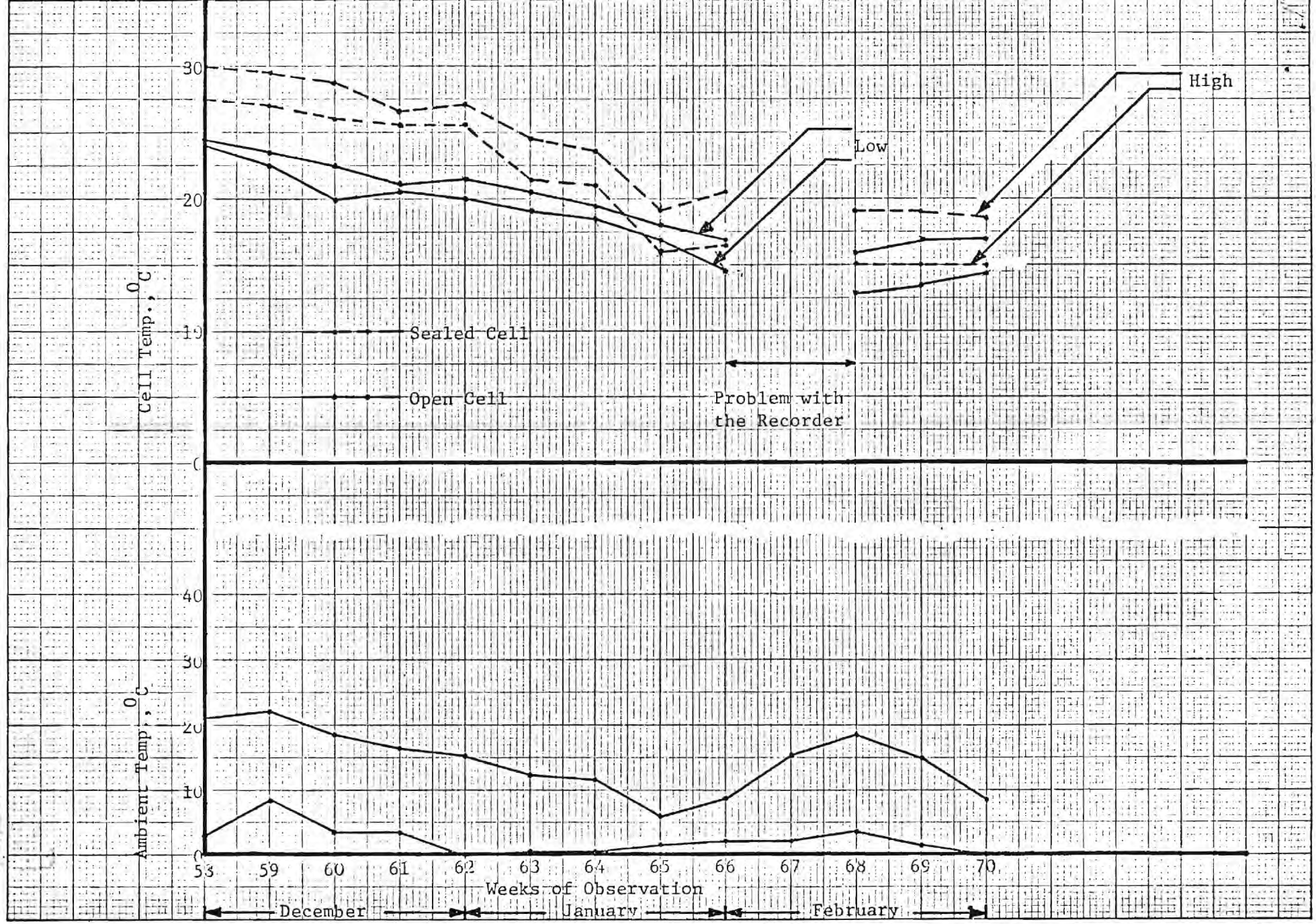
Major effort toward the end of this report period has been directed towards inspection of the integrity of the units against loss of both liquid and gas in the test cell and liquid in the open cell. Excavations around the foundations have indicated some disintegration of joints which are now being repaired. In addition, the cells are being recoated on the outside with a sealer and new cement has been poured around connections between the cells and piping leading to the collection sumps. Gas testing of the closed cell has also been scheduled; regular leachate recycle has been delayed until sealing has been completed so that any gas production during active methane fermentation can be measured and analyzed.

Since controlled leachate recycle was not possible during freezing temperatures and while a portion of the contents of the cells was frozen, routine analyses were not possible. However, grab samples have indicated that the concentration of leachate constituents reported in the previous quarterly progress report have been essentially sustained. With the onset of regular recycle in both cells, routine and more representative concentration data will be acquired from which more definite interpretations will be provided.

Based on previous work, it is anticipated that the next increment of the project period will be crucial with respect to recording the behavior of the leachate components when subjected to opportunties for accelerated stabilization. Therefore, preparations have been made to provide for routine sampling and analysis in order that all trends can be detected and subjected to interpretive analysis.

Frederick G. Pohland
Project Director





E-20-614

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

June 1, 1978

TELEPHONE:
(404) 894-2265

Mr. Dirk Brunner, Project Manager
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Enclosed are five copies of our eleventh quarterly progress report on project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period March 1, 1978 to May 31, 1978. I have again included cumulative data on temperature, relative humidity and rainfall as well as data on selected parameters. Additional data will be provided in the next report when all the analyses have been completed and evaluated.

I hope you have received the proposal for additional support for repair of the simulated landfills which was submitted recently. In anticipation of this support, we have proceeded in the renovation program to accommodate our studies on investigation of the fate of heavy metals in landfills. We appreciate your continuing support of our research and would be pleased to submit additional information as may be required.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

Enclosures
FGP:jp
cc: J. E. Fitzgerald
Phyllis Oliver

P.S. I will be leaving for Europe on June 4 and will be basically out of touch until my return on June 21, 1978.

cc: Al Bicker, w/rpt.

SKB

Quarterly Progress Report No. 11

"Controlled Landfill Stabilization by Leachate Recycle"

EPA Grant No. R-8039353-02

Research Project E-20-614

Georgia Institute of Technology

Atlanta, Georgia

March 1, 1978 - May 31, 1978

This report period has been one of considerable activity. With the onset of a recirculation program, several leaks occurred in the containment structures, particularly in the open cell. This problem has now been brought under control and the normal operation schedule is proceeding without difficulty. The recycle schedule now includes daily pumping of 200 gallons of leachate through each respective cell. This has permitted more frequent and reliable sampling of both leachate and gas at intervals of about 5 to 7 days. This interval may be changed depending upon need as determined by variations in analytical results.

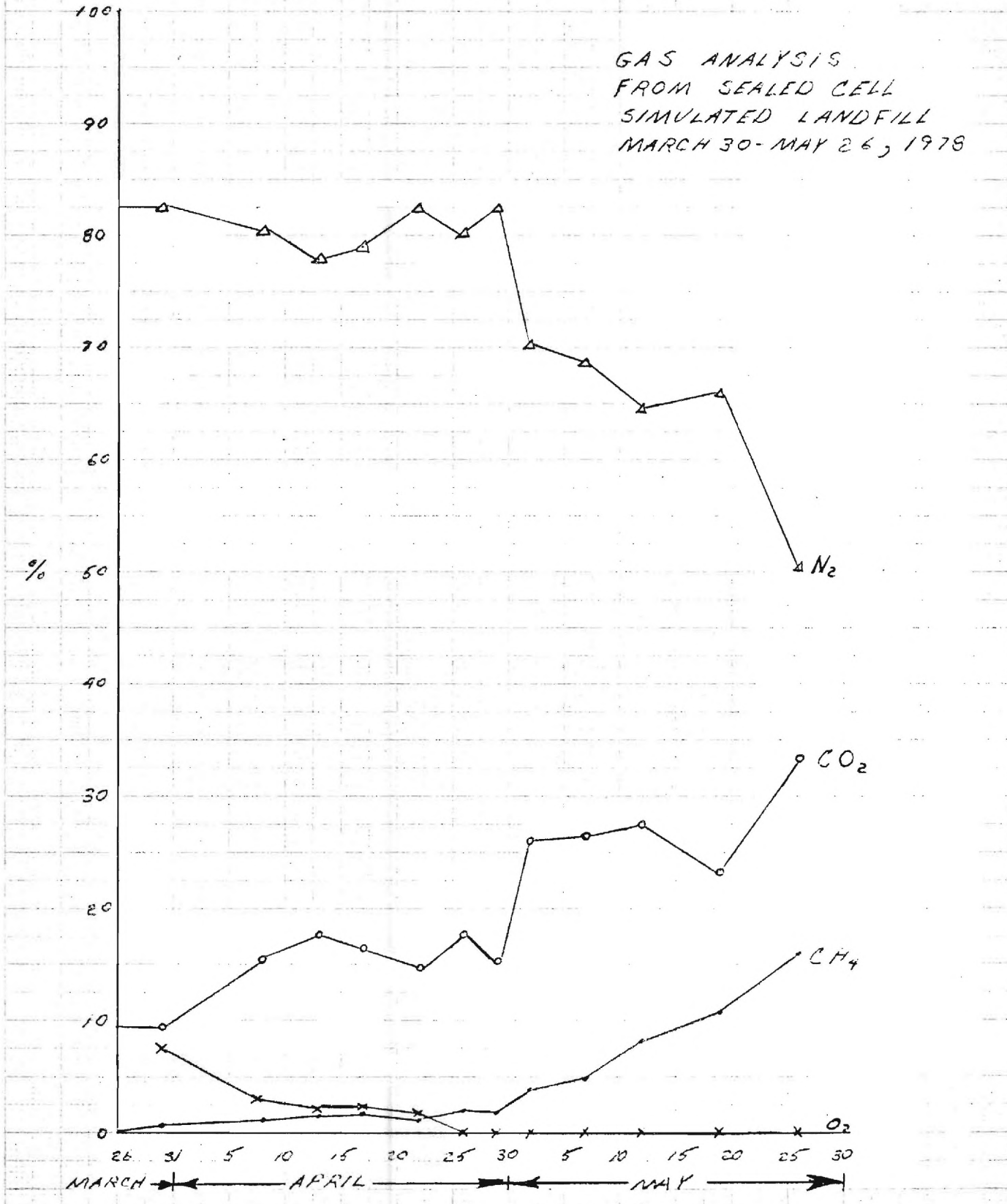
Monitoring of temperatures, rainfall and relative humidity has continued during this report period as indicated on the attached figures. Some earlier problems were encountered with the recorders, but these have been essentially resolved. Included also are selected data on changes in leachate COD, total solids, TOC and closed cell gas analysis. Quantification of gas has not yet been possible since the production apparently is still below the sensitivity of measurement capabilities with the wet test meter (2.4 liters per day). Liquid displacement for this purpose has also yielded irregular results with very low total yields being suggested at this time even with assurances of a gas-tight system. However, the oxygen in the closed cell has disappeared and the nitrogen is decreasing as the relative carbon dioxide and methane contents are increasing. The data on the other illustrated parameters are from the first date of measurable leachate appearance in early September 1977; the daily recirculation schedule was commenced on March 27, 1978.

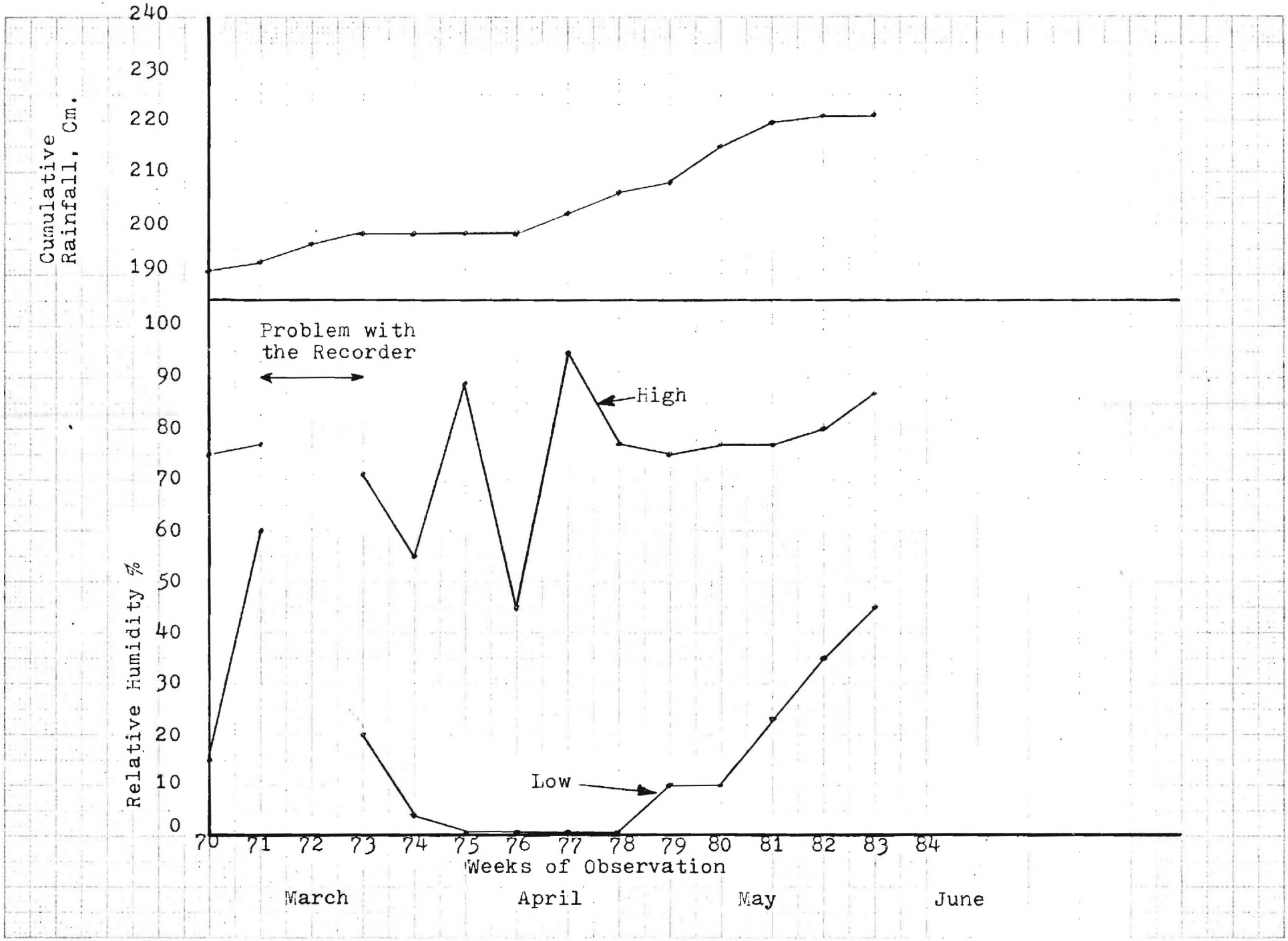
In addition to the illustrated trends in analytical parameters, other analyses have been performed including metals which peaked in December 1977 and have since declined probably because of better distribution due to recycle. The most notable decrease has been for iron which has declined from 1950 mg/1 to 880 mg/1. Copper, aluminum and lead have not been detectable so

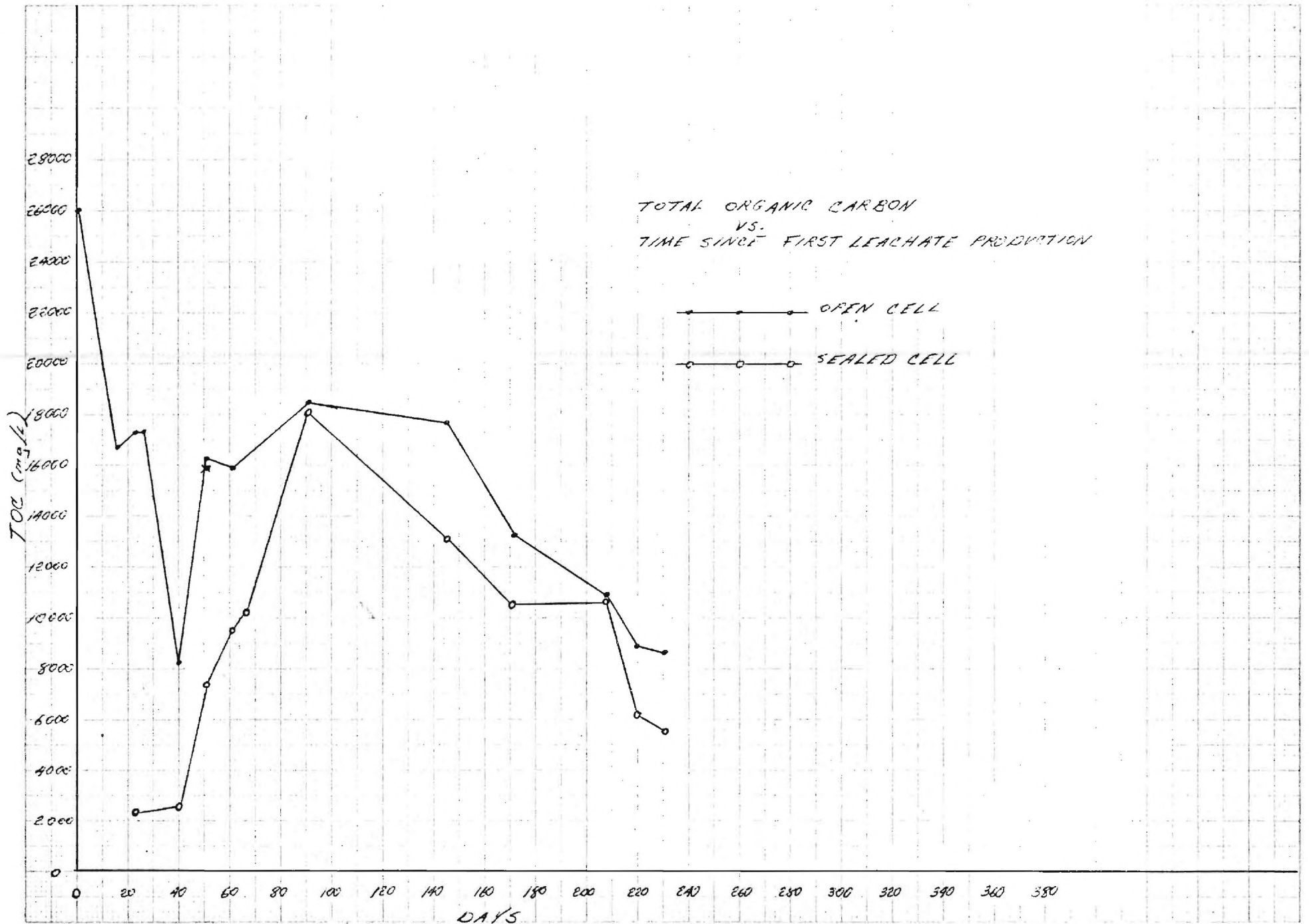
that their continued analysis will be performed at a less frequent interval. Also during this report period, BOD_5 and oxidation reduction potential measurements have been included on a routine basis. As with COD, a concomitant decline in BOD_5 has been observed and the pH has risen from a low of 4.85 to 5.65. This would be expected as the volatile acids are converted to gas and effectively removed from the system. It is anticipated that the pH will continue to rise toward neutral as the leachate constituents are stabilized.

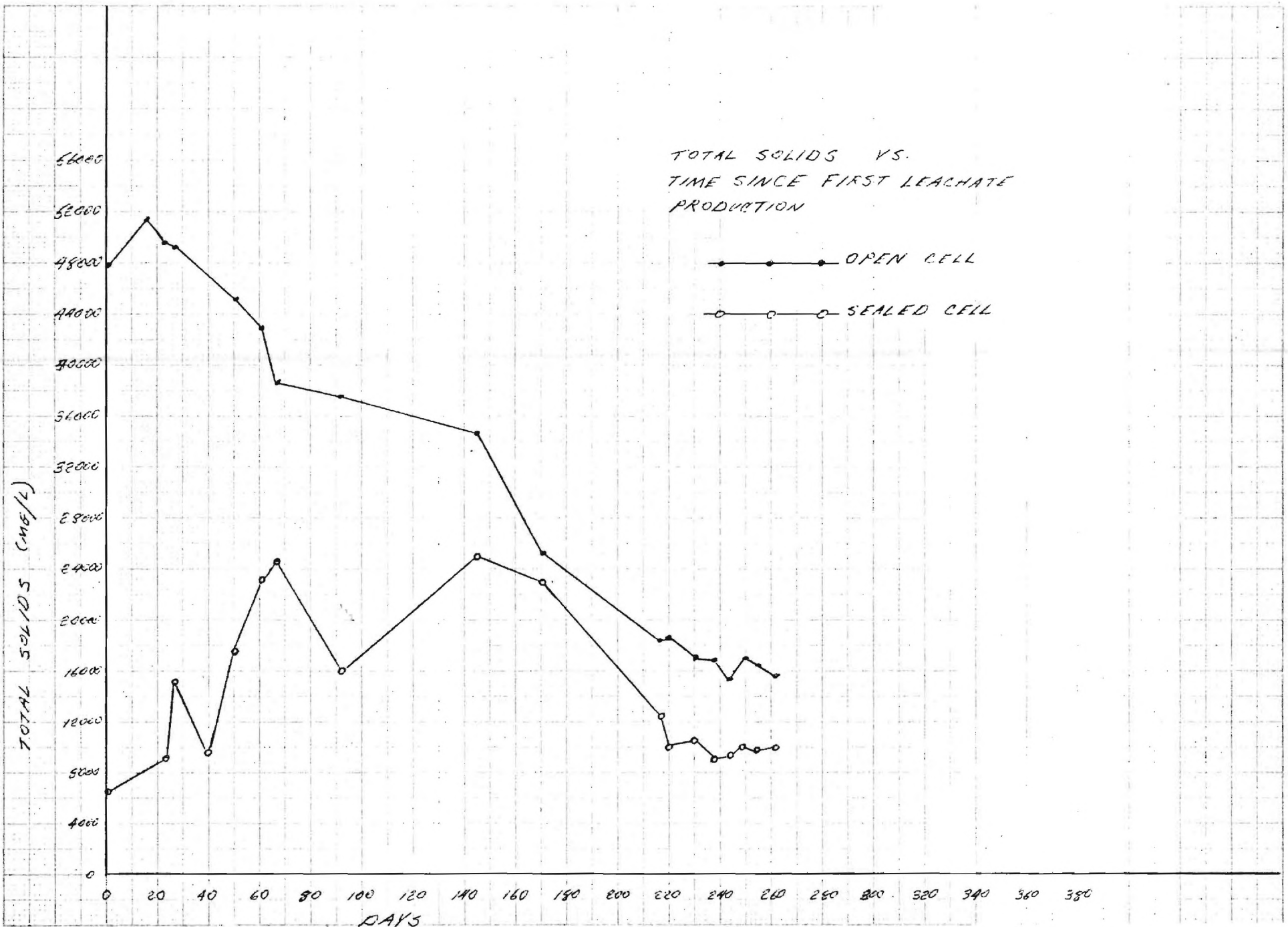
The onset of warmer weather coupled with a more active methane fermentation should enhance more rapid stabilization during the next project period. Accordingly, sampling and analyses will be intensified in order to properly record changes in parametric analyses. Based on the previous column studies, the trends suggest that the removal of readily available organic constituents within the leachate will occur within the remaining grant period.

Frederick G. Pohland
Project Director


GAS ANALYSIS
FROM SEALED CELL
SIMULATED LANDFILL
MARCH 30 - MAY 26, 1978
100
90
80
70
60
%
50
40
30
20
10
0
N_2
CO_2
CH_4
O_2
26
31
5
10
15
20
25
30
5
10
15
20
25
30
MARCH
APRIL
MAY


Cumulative Rainfall, Cm.
240
230
220
210
200
190
Problem with the Recorder
High
Low
Relative Humidity %
100
90
80
70
60
50
40
30
20
10
0
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
Weeks of Observation
March
April
May
June


TOTAL ORGANIC CARBON
VS.
TIME SINCE FIRST LEACHATE PRODUCTION
OPEN CELL
SEALED CELL
TOC (mg/L)
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
DAYS


TOTAL SOLIDS VS.
TIME SINCE FIRST LEACHATE
PRODUCTION
OPEN CELL
SEALED CELL
TOTAL SOLIDS (MG/L)
56000
52000
48000
44000
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
DAYS


TOTAL COD (MG/L) VS. TIME
SINCE FIRST LEACHATE PRODUCTION
OPEN CELL
SEALED CELL
COD (mg/L)
68000
64000
60000
56000
52000
48000
44000
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380
DAYS

E 20-6

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 894-2265

September 8, 1978

Mr. Dirk Brunner, Project Manager
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Enclosed are five copies of our twelfth progress report on project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period June 1, 1978 through August 31, 1978. I have again included data on selected parameters to demonstrate present trends along with a brief discussion of their interpretation and some of the problems that have been encountered with the recycle and gas collection systems. We find the results to date quite encouraging and a reinforcement of some of our previous concepts.

Unfortunately, I had hoped to include our economic feasibility analysis of leachate recycle which is in draft form but which will now follow to avoid delays in your receipt of this report. Although we would consider this feasibility analysis tentative, we would also hope to demonstrate that leachate recycle is probably the cheapest of all separate leachate treatment schemes which becomes even more attractive if some values are assigned to the relative degrees of process predictability and control as well as the opportunity for rapid realization of a site's ultimate use potential. Some of the delay here is due to an attempt to be as objective as possible and I felt that I should at least consider the emerging interest in energy recovery. Please be assured that this analysis is forthcoming and I trust its delay will not jeopardize our request for support for an extended investigation with landfilling heavy metals. I would like to formalize this latter request and would therefore appreciate receiving your comments and suggestions.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

Enclosures
FGP:jp
cc: J. E. Fitzgerald
Phyllis Oliver

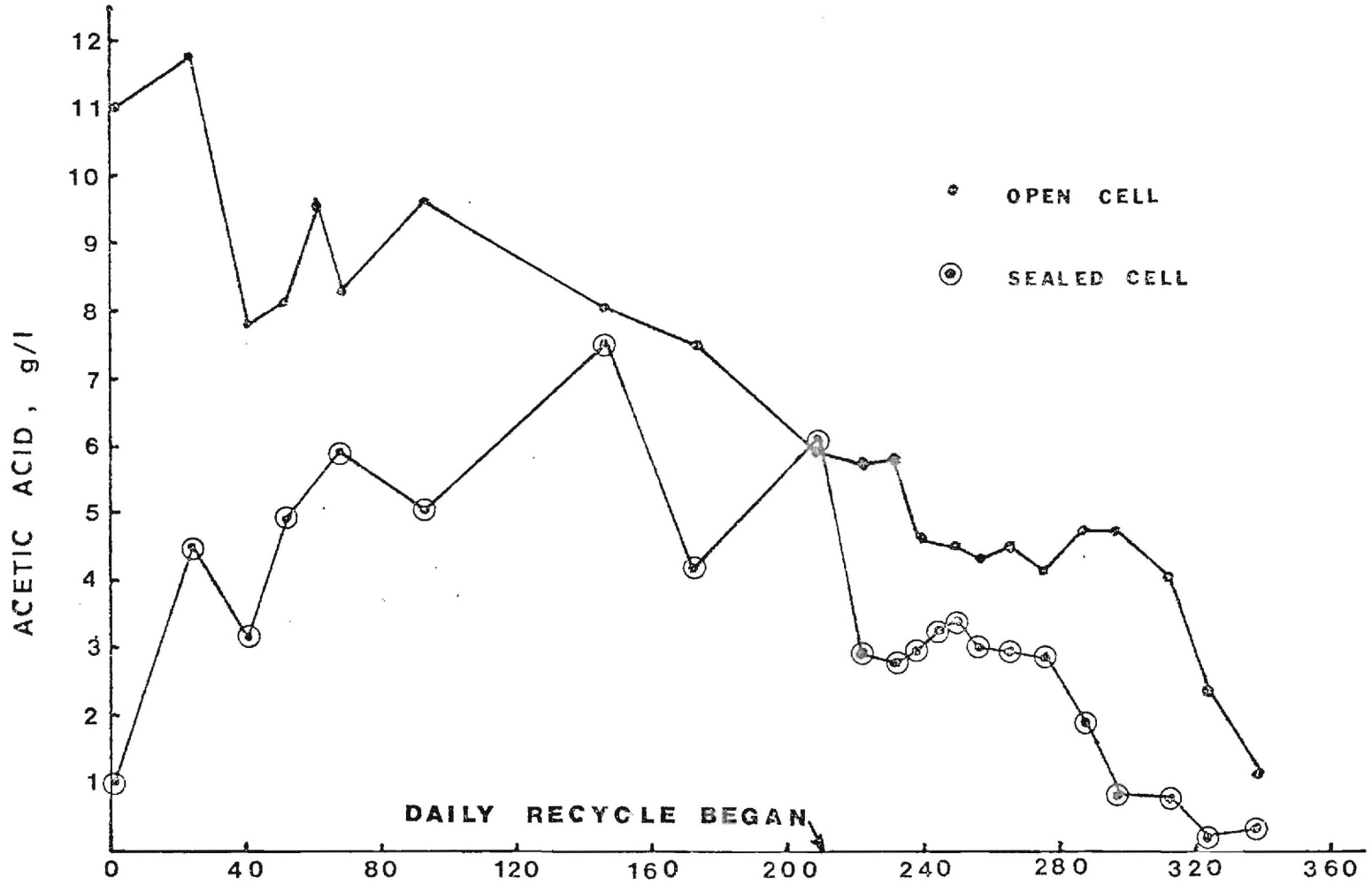
Quarterly Progress Repirt No. 12

"Controlled Landfill Stabilization by Leachate Recyle"
EPA Grant No. R-8039353-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
June 1, 1978 - August 21, 1978

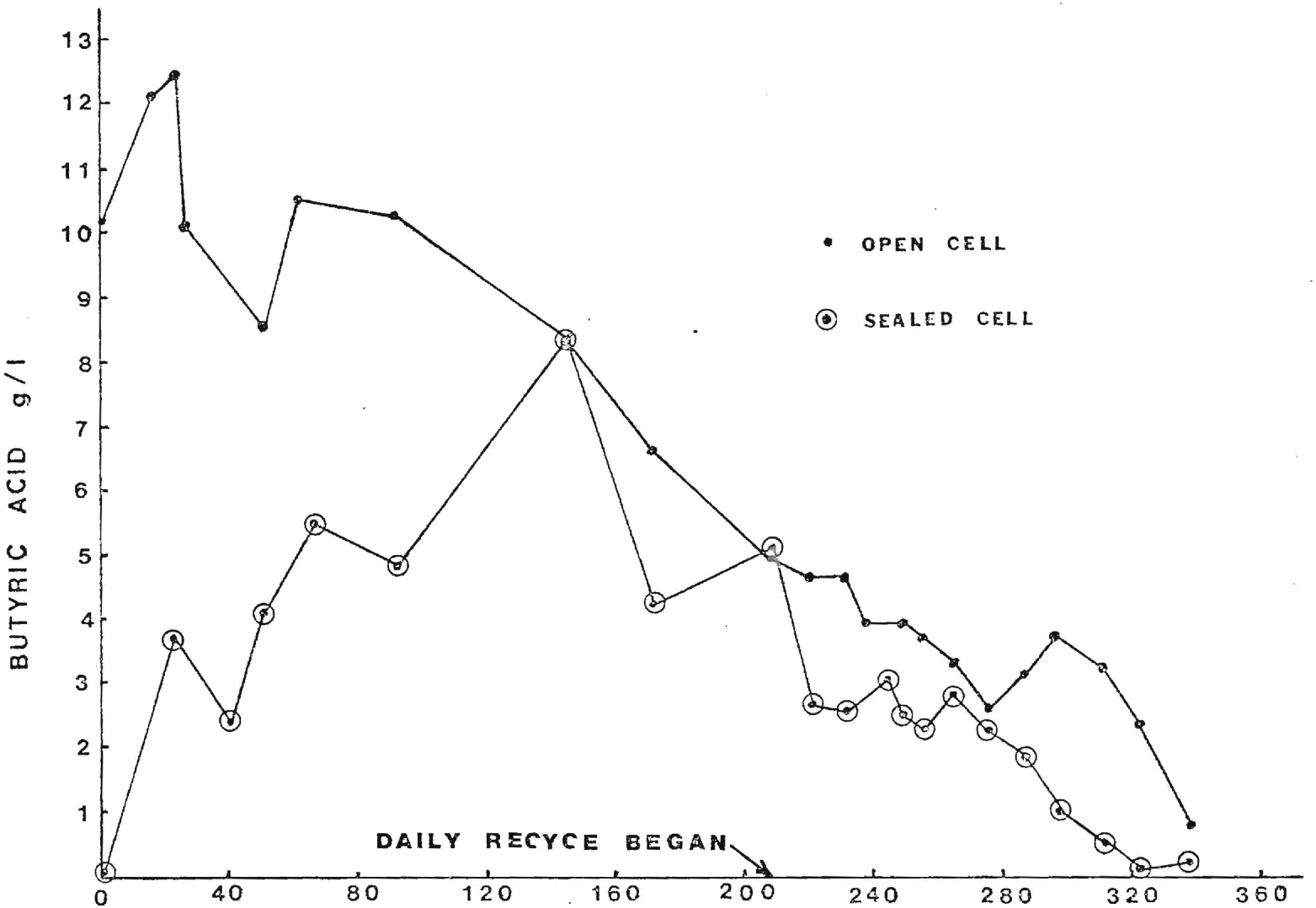
This report period has again produced significant results with the daily recycling of leachate through each of the experimental landfills. However, since more time is now being required to accumulate and recycle this quantity in each cell, the system has been placed in an automatic mode of operation. To accumulate leachate, the collection line in the open cell is allowed to drain continuously since more time was required each day for the collection process in the open cell than in the closed cell. The collection line in the closed cell is opened for five hours each day which allows about the same amount of leachate to be acquired as in the open cell. Because of this constraint in the closed cell, only about 100-130 gallons per day are presently being recycled in each unit.

Monitoring for indicator parameters has continued throughout this report period as indicated in the attached figures. Most of these data are plotted from the time recirculation was commenced with daily recycle being initiated on March 27, 1978. Accordingly, the data presented include a continuation of the data trends reported in the last project period. All of these trends indicate very active biological activity in both units with concomitant reductions in organic leachate constituents as measured by the volatile acids, organic carbon and COD. Corresponding and logical changes in alkalinity, pH and conductivity have also occurred, all reflecting conditions most conducive to methane fermentation. This latter aspect has been confirmed by the increases in gas production which continue to occur; with daily gas collection commenced on July 4, 1978, over 25,000 liters of gas have been since measured containing over 50% methane. The relative composition of the gas illustrated in the figure also indicates that methane fermentation was enhanced by the elimination of oxygen. The remaining gas component not shown was nitrogen which yet remains as a gaseous constituent within the cells.

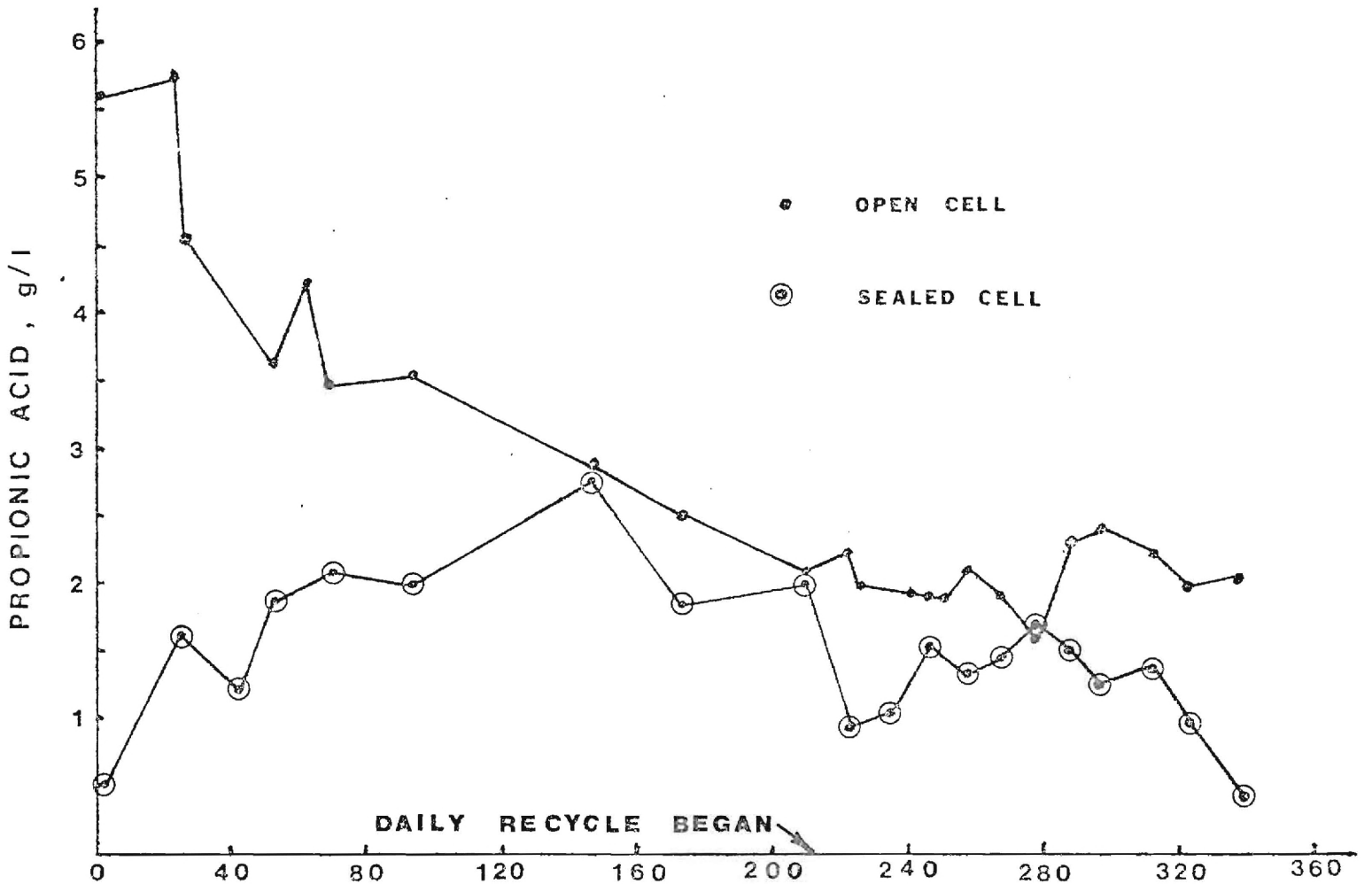
Collection of the gas from the closed cell emerged as an unanticipated problem in that the gas was apparently being produced more in the totally



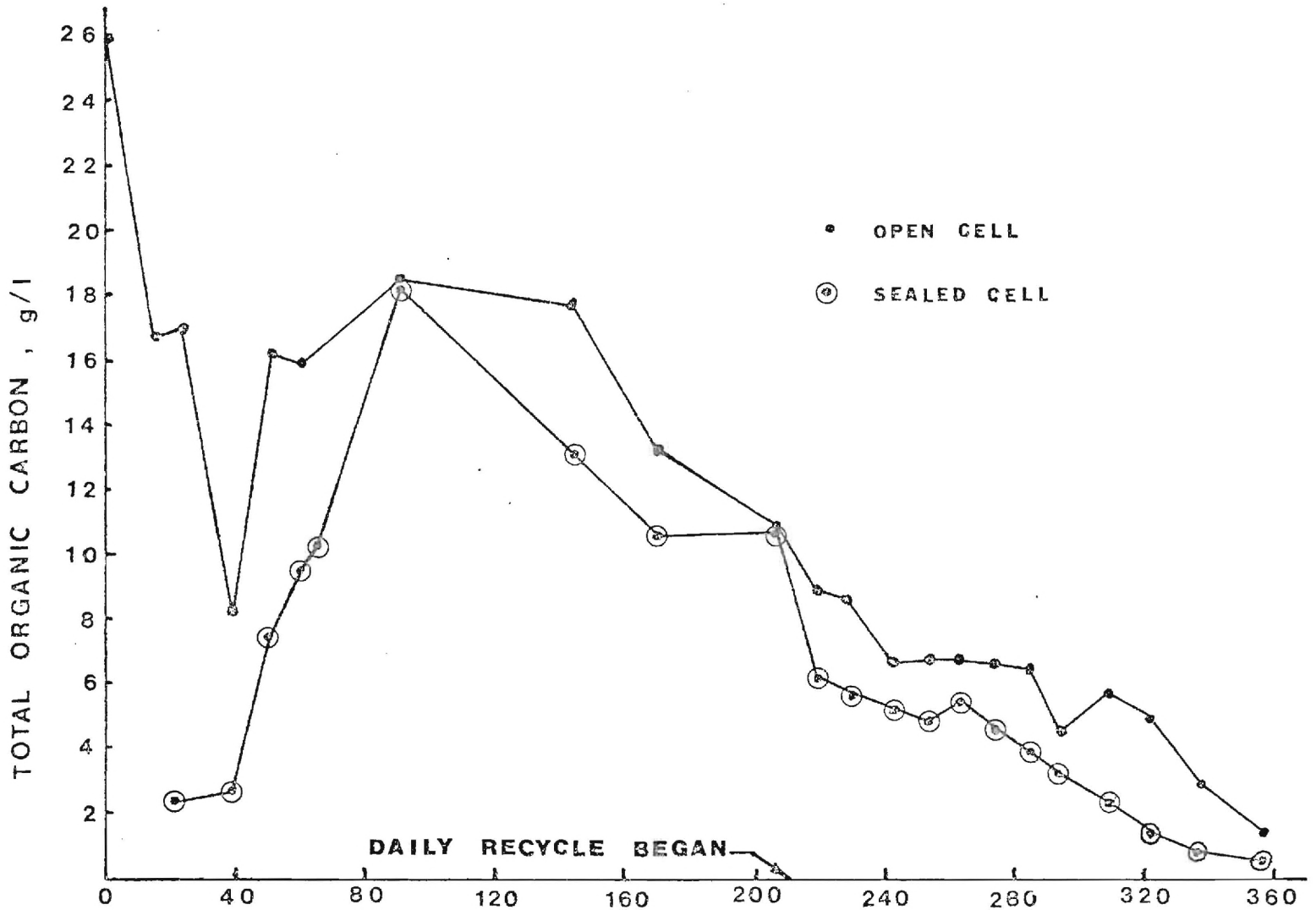
ACETIC ACID CONCENTRATION OF LEACHATE



BUTYRIC ACID CONCENTRATION OF LEACHATE

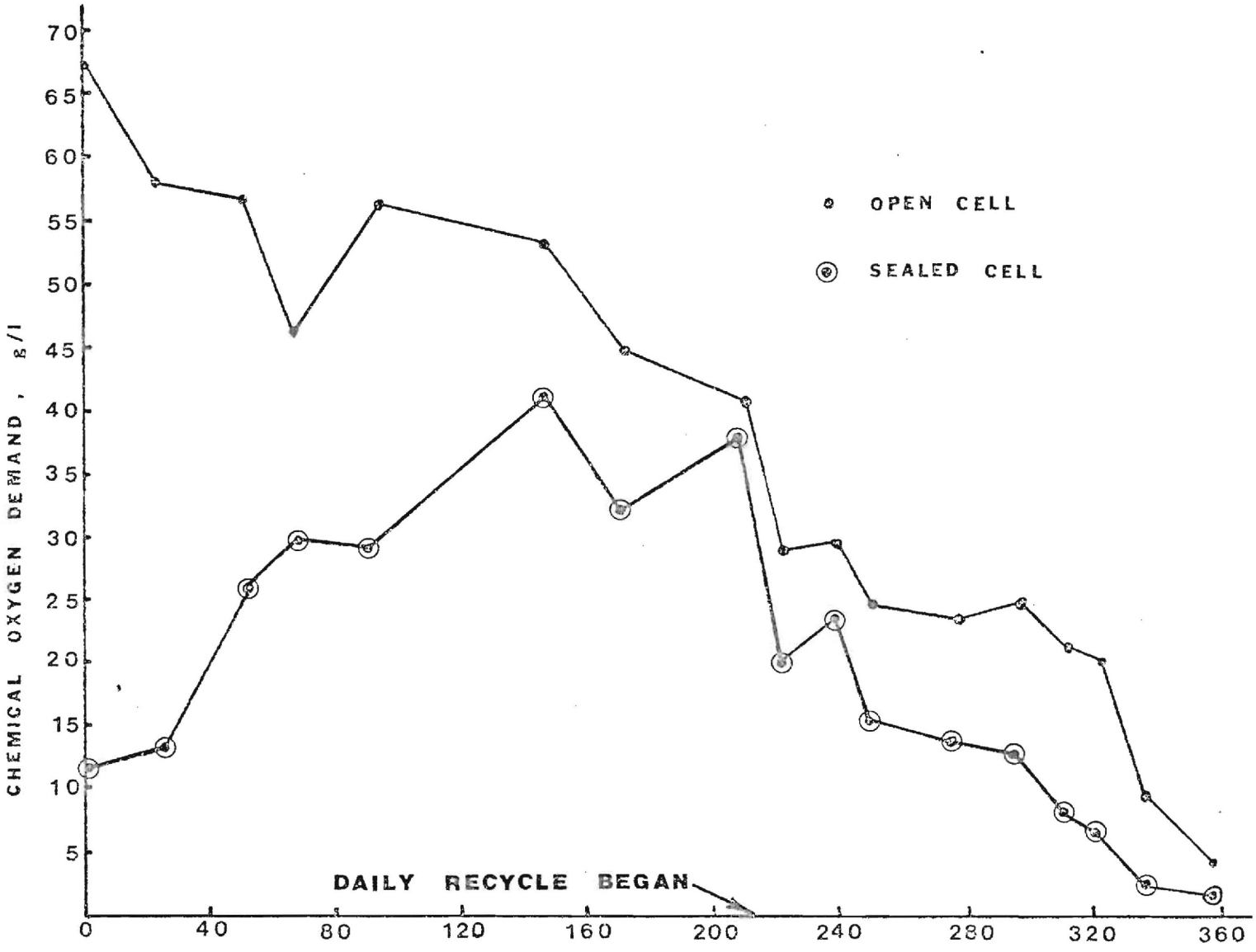


PROPIONIC ACID CONCENTRATION OF LEACHATE

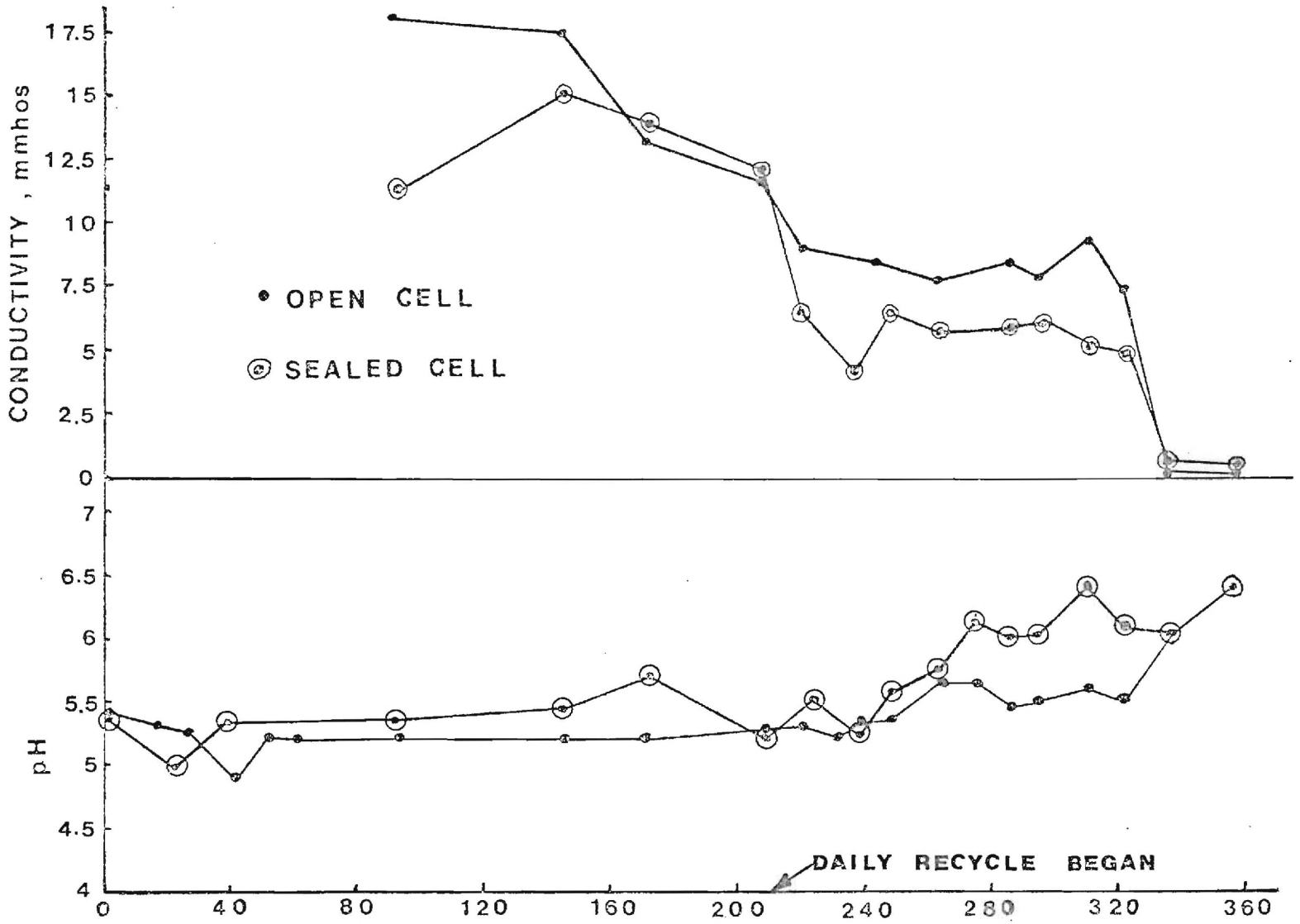


TIME SINCE RECIRCULATION BEGAN , days

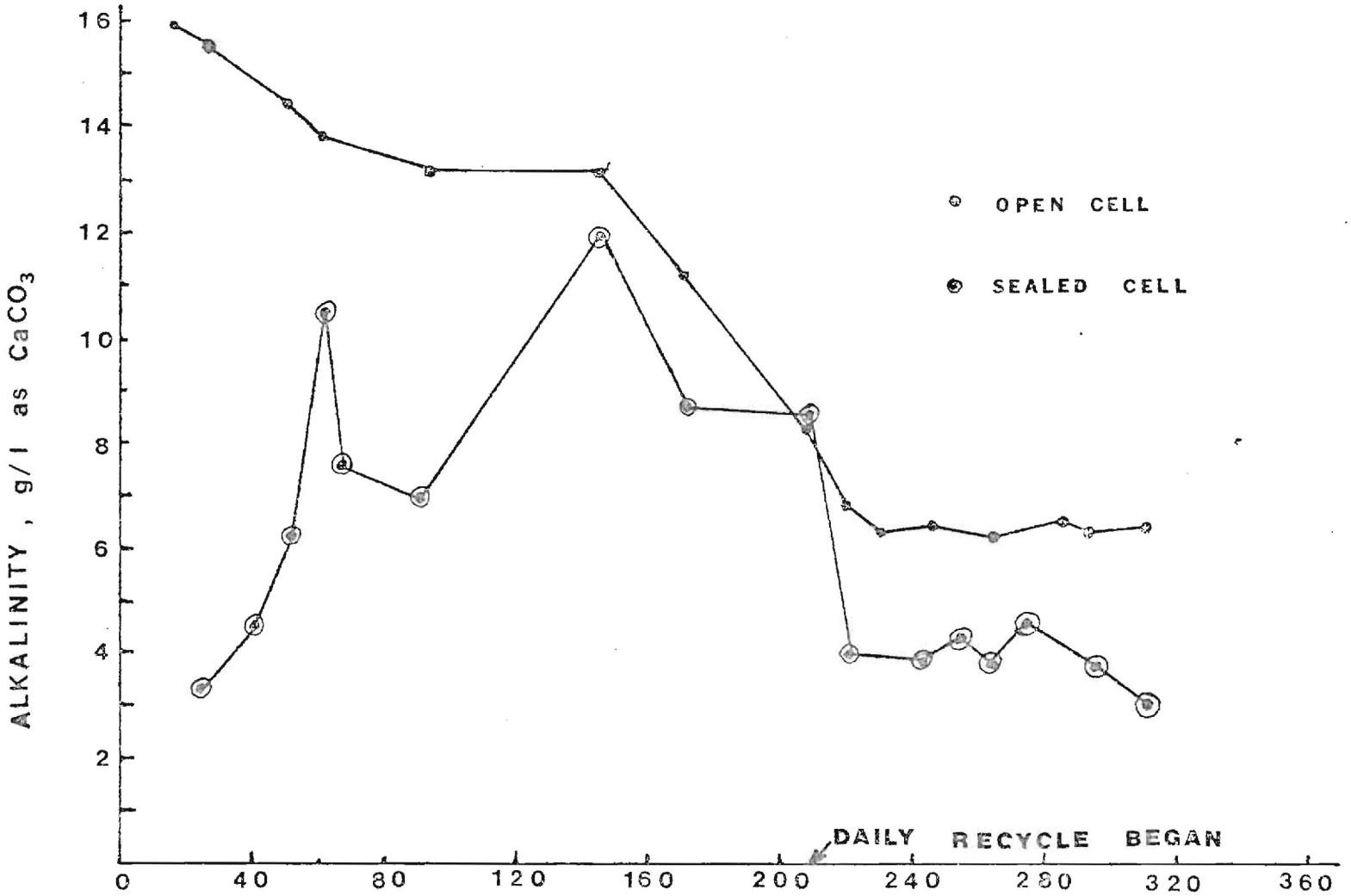
TOTAL ORGANIC CARBON OF LEACHATE



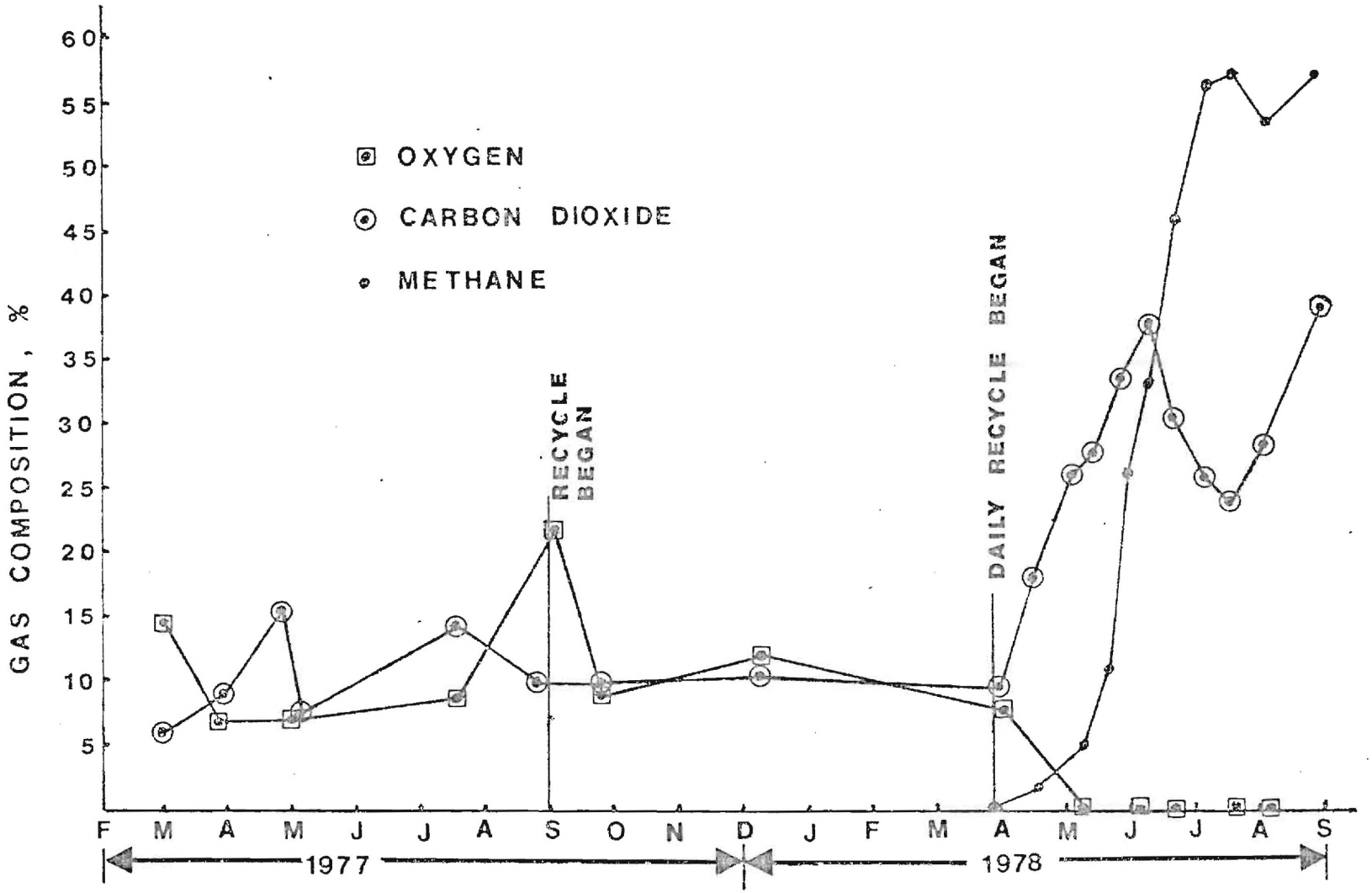
CHEMICAL OXYGEN DEMAND OF LEACHATE



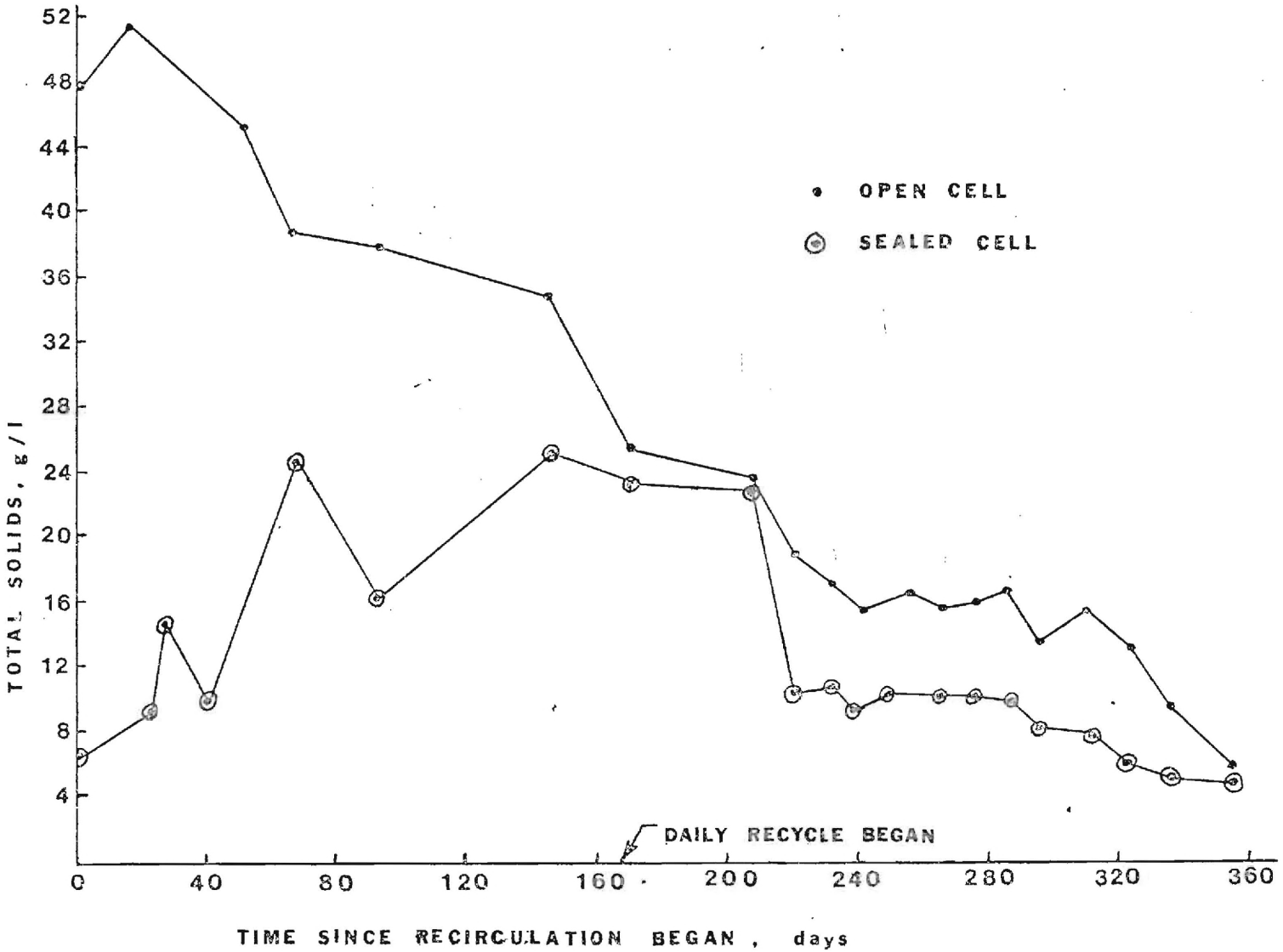
pH AND CONDUCTIVITY OF LEACHATE



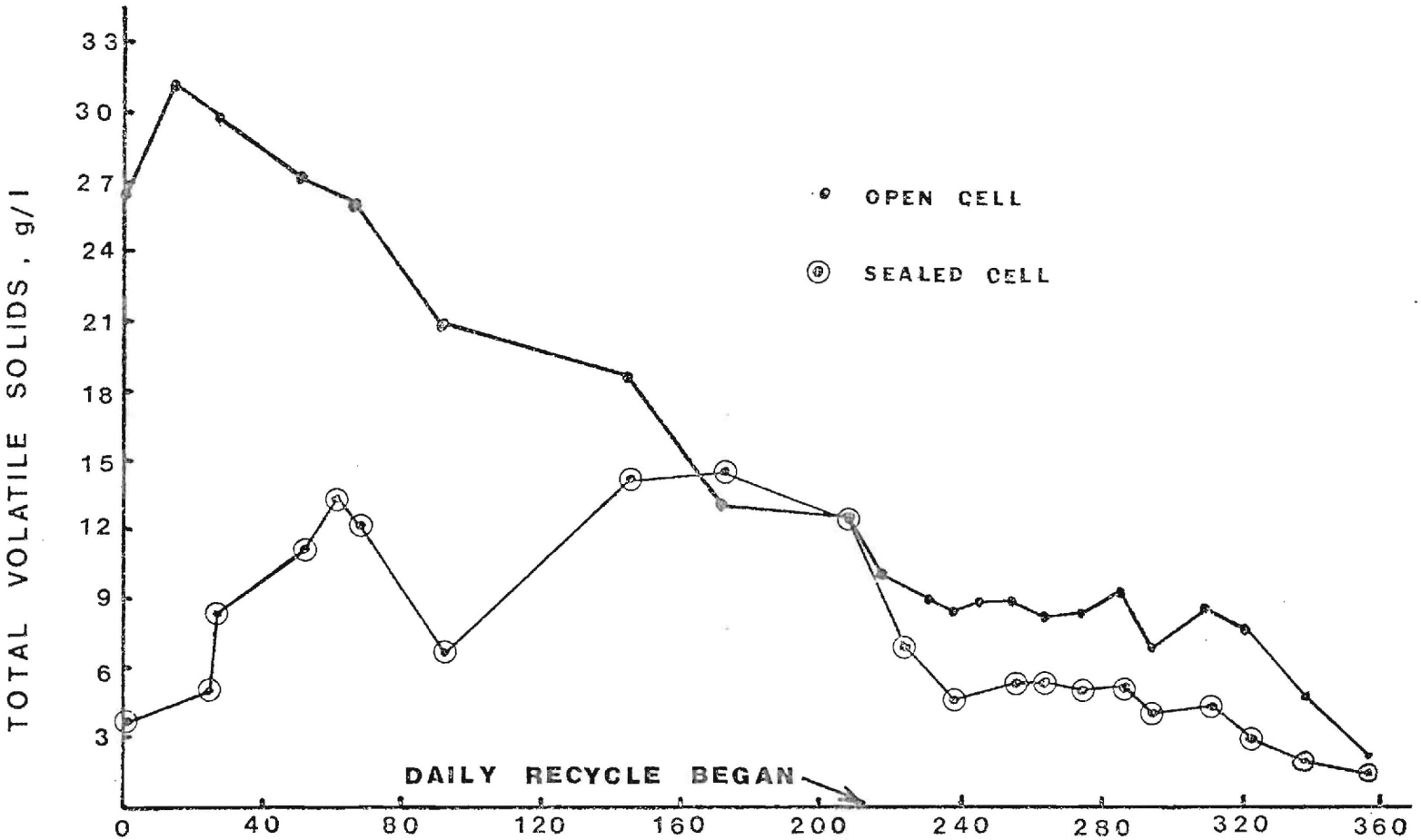
ALKALINITY OF LEACHATE



GAS COMPOSITION FROM A SANITARY LANDFILL



SOLIDS CONCENTRATION OF LEACHATE



TOTAL VOLATILE SOLIDS OF LEACHATE

saturated zone of the fill and was not moving freely upward into the gas collection systems. Consequently, gas was not detected in quantity at the surface collection points but rather was being forced under pressure through the leachate collection system and released when the valves were opened to the collection sumps. Fortunately, this problem was apparently detected before rapid stabilization and gas production had commenced and could be remedied by installation of a gas collection system installed to tap the gas reservoir at the bottom of the fill. With this technique, over 600 liters of gas production are presently being recorded each day with an adjusted methane content of 68% (assuming only CO_2 and CH_4 constituents). Because of the success of this procedure, gas measurements are now being taken solely at the bottom leachate collection location and a parallel system is being fabricated for the open cell presuming that a similar condition prevails.

Just why it has been difficult to recycle the initially selected 200 gallons of leachate each day, particularly in the open cell, and why the gas is not permeating freely through the mass in the closed cell are matters for speculation at this time. It has been established that the total solids content of the leachate has decreased with time which may mean that some of the interstices in the fills have been clogged. Furthermore, shredding the solid wastes before placement provides for a much more compact bulk particularly after it had been saturated with water. Therefore, these combined effects, including in the case of the recycle flow, the gas pressure built up by accelerated biological activity, may be restricting both liquid and gas flow through the two landfill masses. These two events are being carefully monitored to establish whether these problems will continue to increase or whether they will diminish as stabilization becomes more complete.

Continued warm weather has encouraged active biological activity even though little additional rainfall or water equivalent has been received recently by the cells. Based upon concentrations of gross organic constituents, this activity may diminish as readily available substrates become depleted. Accordingly, barring any unforeseen circumstances, progress toward realization of the project objectives is presently considered to be on schedule.

Frederick G. Pohland
Project Director

E-20-61

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

December 5, 1978

TELEPHONE:
(404) 894-2265

Mr. Dirk Brunner, Project Manager
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Included herewith are five copies of our thirteenth progress report on project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period September 1, 1978 through November 30, 1978. In addition to the summary data presented in our last report, I have included companion data on BOD_5, total volatile acids, ORP, TSS, TKN, NH_3-N, phosphate, chlorides, sulfates, and metals. These data again demonstrate a continuation of the recent trends which have been established toward leachate stabilization.

We are proceeding with our plans for utilization of the four rejuvenated columns for the proposed heavy metal/landfill project (R-806498-01) which you presently have under review. To maintain the continuity of effort and continue supporting student assistants to accommodate this project, it is critical that we receive early notification of action taken on our proposal. I trust that the review of this proposal has been favorable and I would be pleased to provide additional information as may be required.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

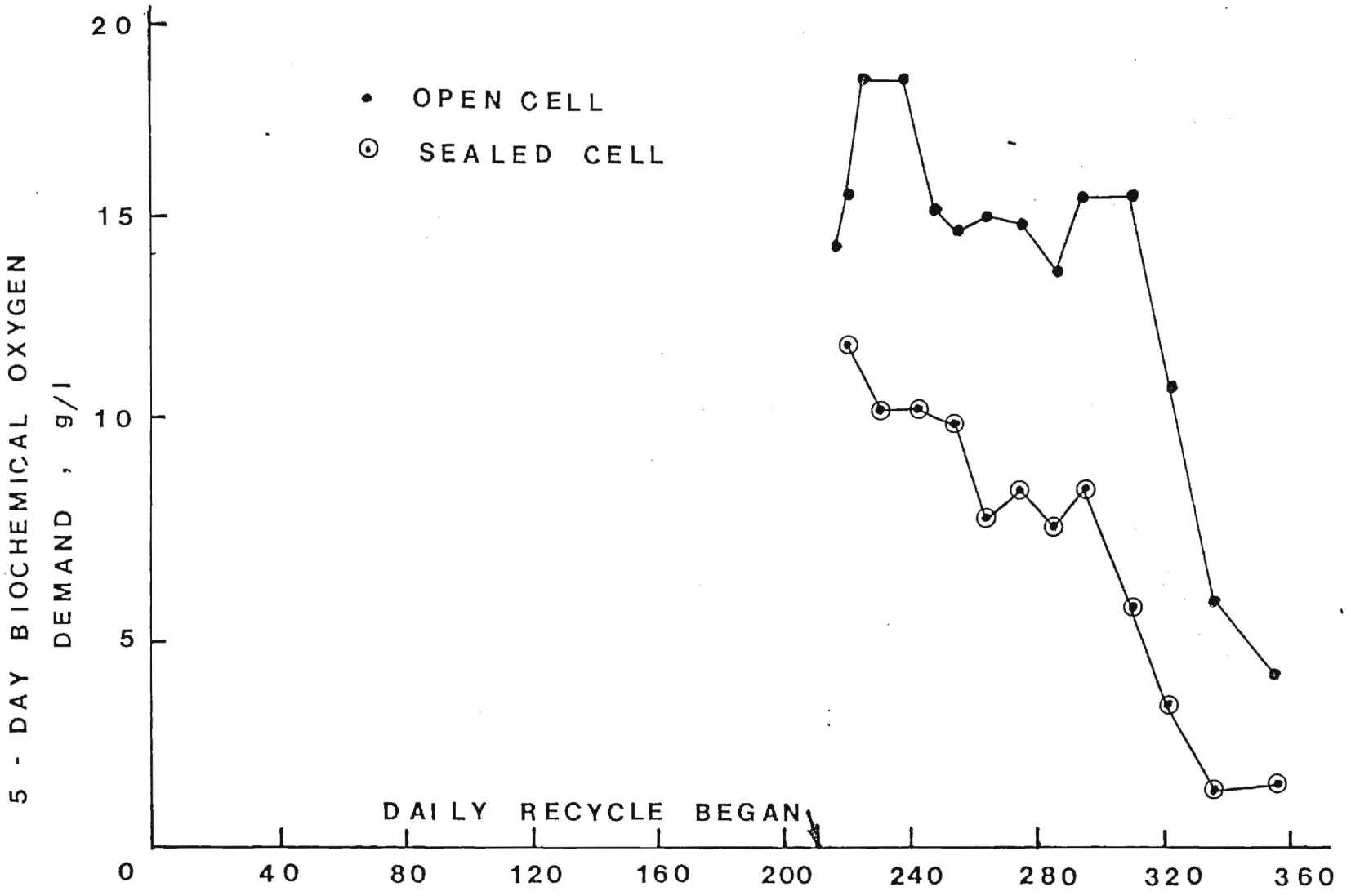
Enclosures
FGP:jp
cc: J. E. Fitzgerald, CE
Phyllis Oliver, ORA

Quarterly Progress Report No. 13

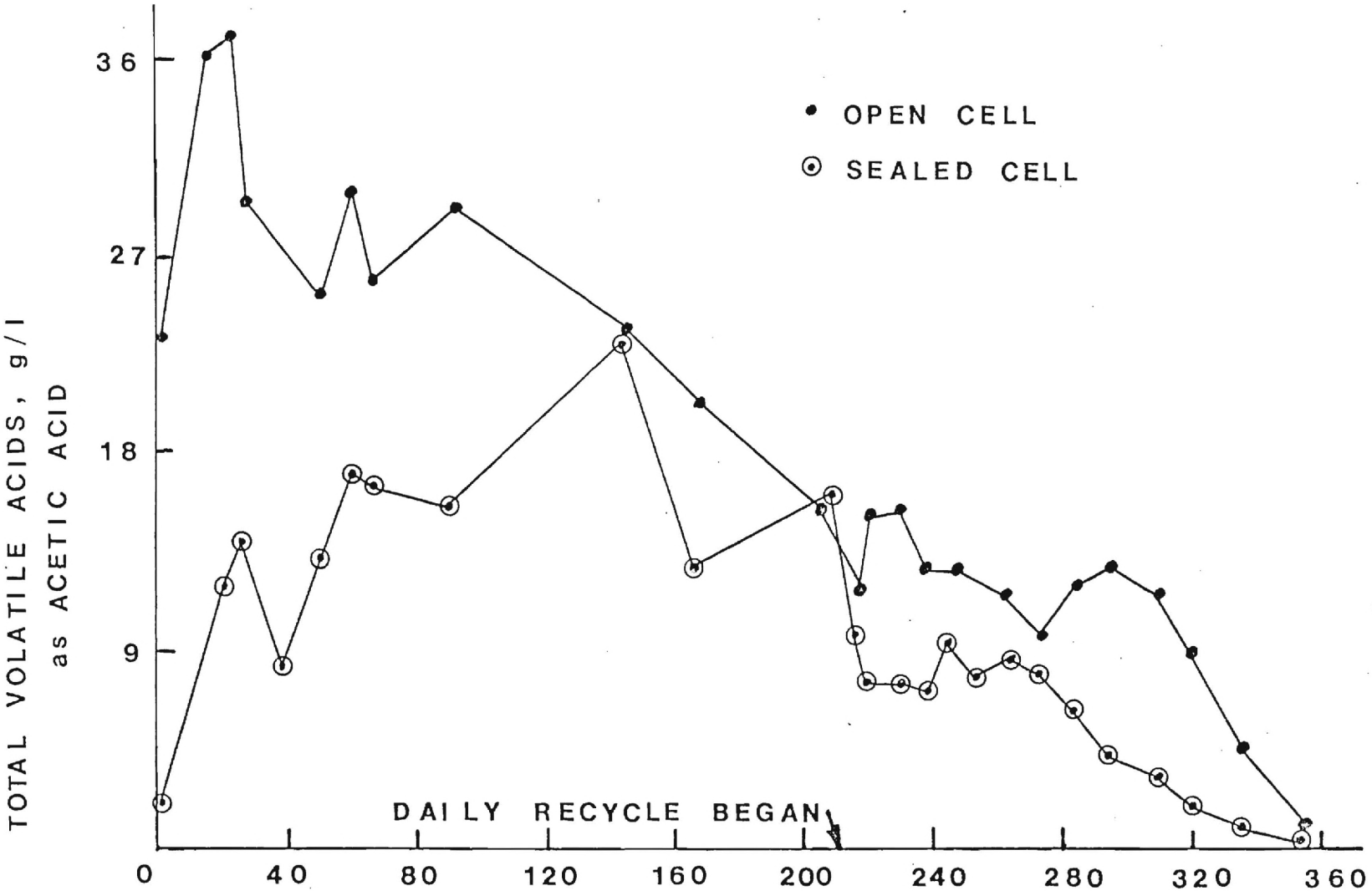
"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-8039353-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
September 1, 1978-November 30, 1978

This report period has continued to reflect anticipated stabilization trends with leachate recycle through the experimental landfills. However, because of the unusually dry weather conditions, the quantity of leachate available in the open cell has diminished and the recycle interval has been accordingly changed from daily to every other day for both cells with about 100 gallons of leachate being recycled through each unit. No other operational problems have been experienced in either the leachate handling or gas collection system. Gas quantities measured each day have decreased somewhat to about 200 liters per day but the quality reported previously has remained essentially the same. With the availability of substrate for methane fermentation, this gas production is expected to continue but at a slowly diminishing volume as the substrate is also reduced.

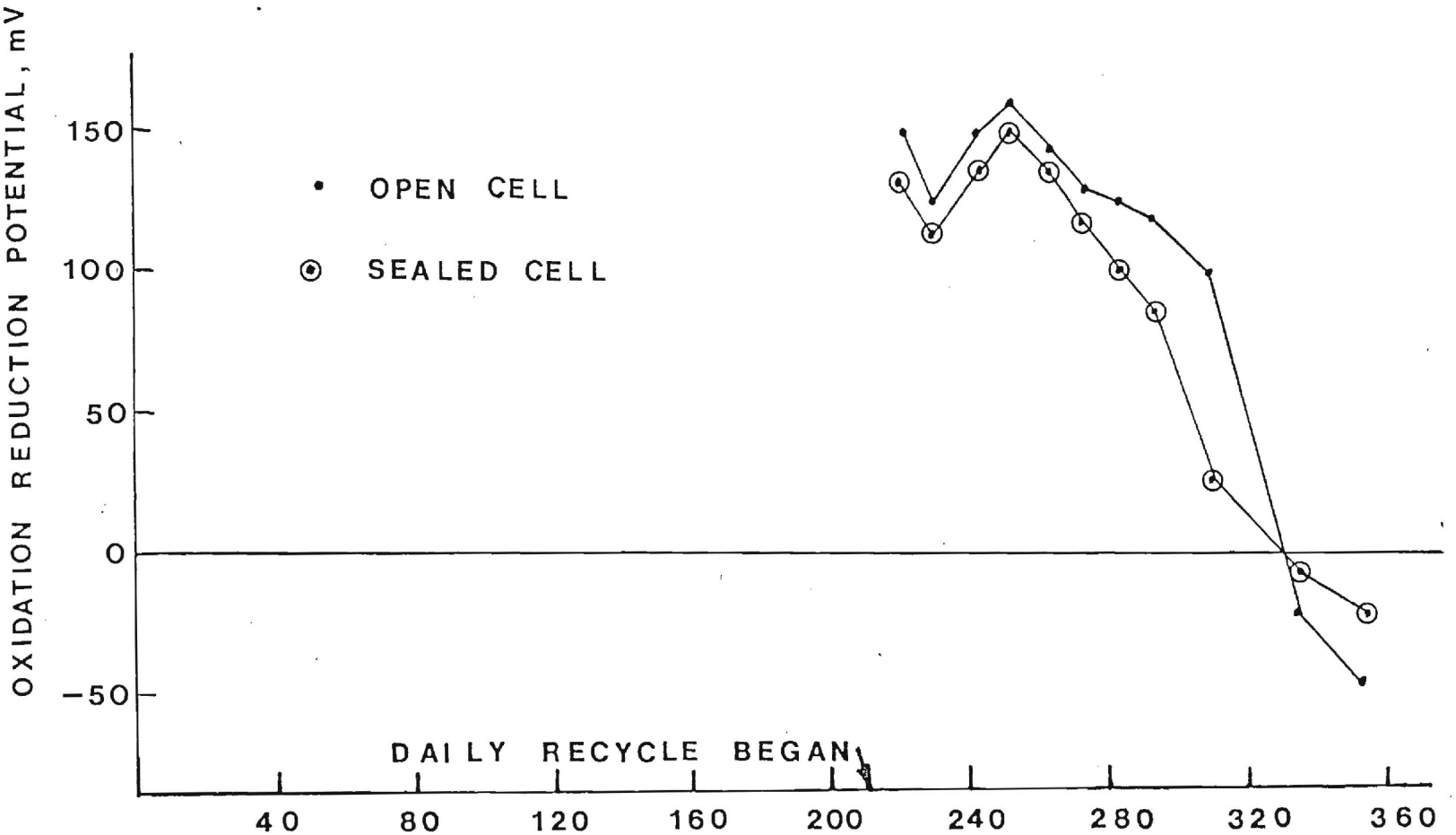
Monitoring for indicator parameters has continued during this report period; additional data on both organic and inorganic constituents as well as ORP are presented on the attached figures as complementary to the data presented in the last progress report for the period June through August 1978. In all cases, the concentrations of parameters indicative of organic pollutants have decreased with BOD, COD and organic acids presently in the hundreds of mg/ℓ range. The more conservative indicator parameters reflect general dilution patterns and possibly the results of physical-chemical interactions within the landfill mass. There is some correspondence between certain of the parameters which should become clearer with time and with eventual measurement of the total quantity of leachate and hence dilution effect available.



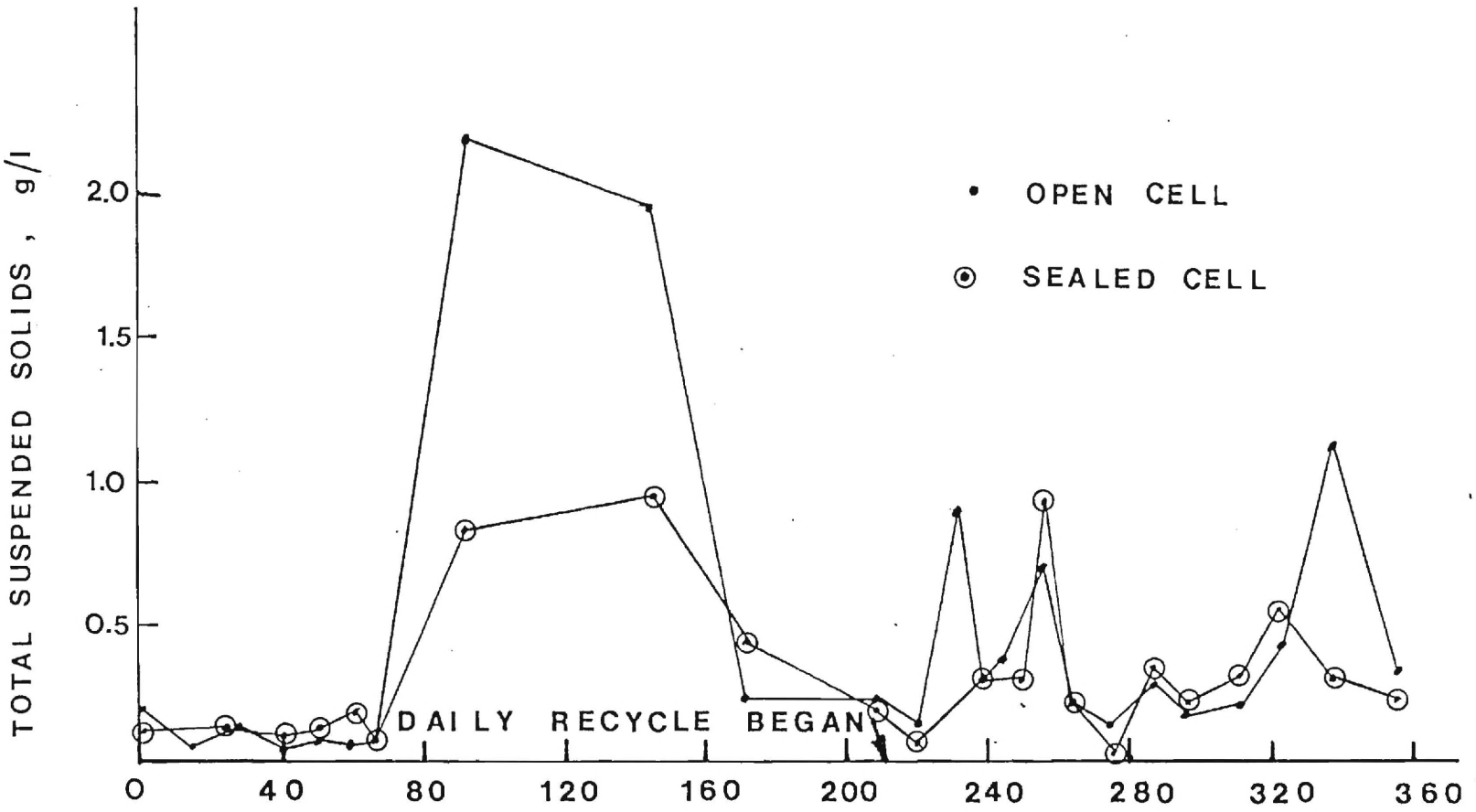
5 - DAY BIOCHEMICAL OXYGEN DEMAND OF LEACHATE



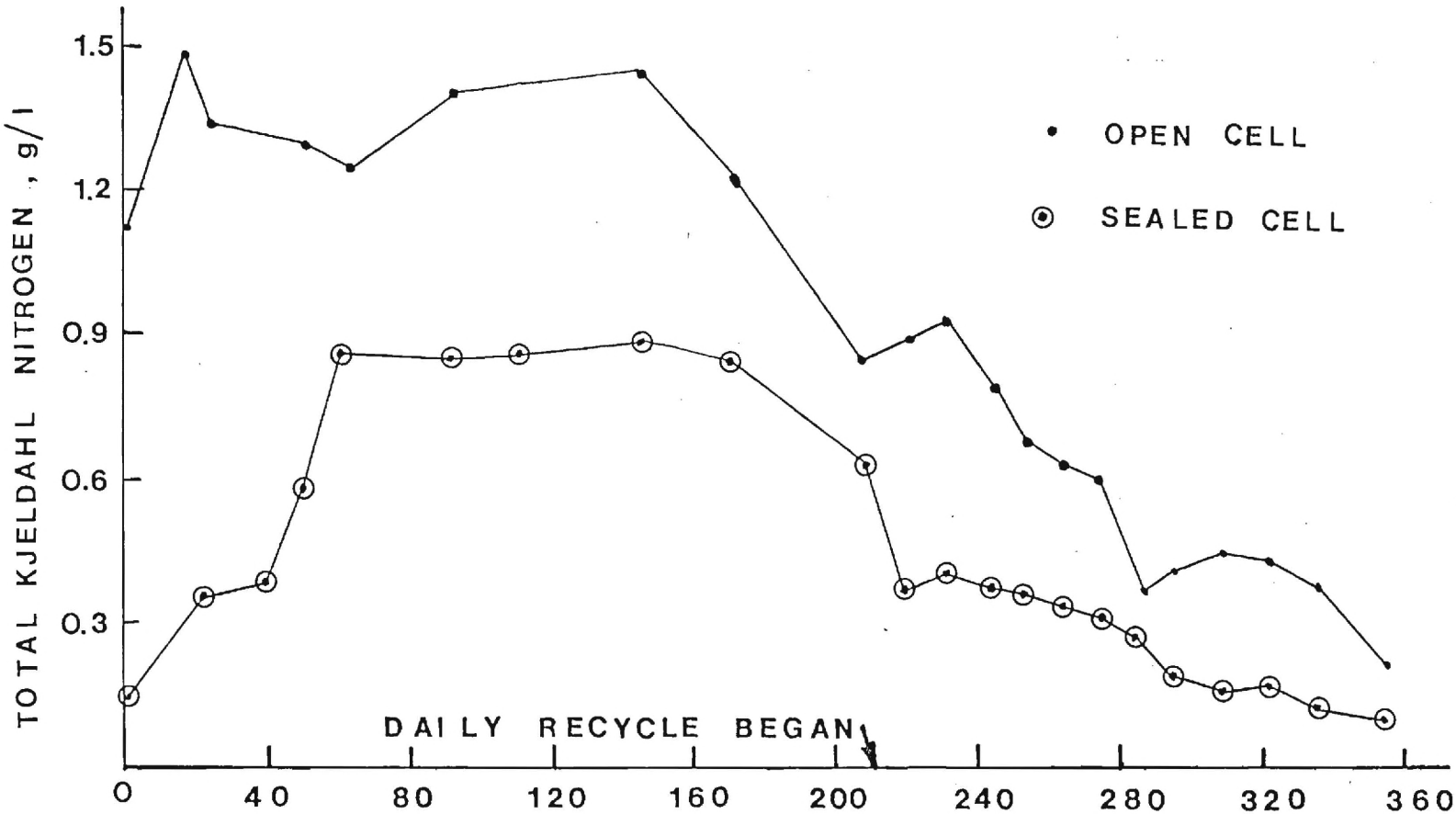
TOTAL VOLATILE ACID CONCENTRATION OF LEACHATE



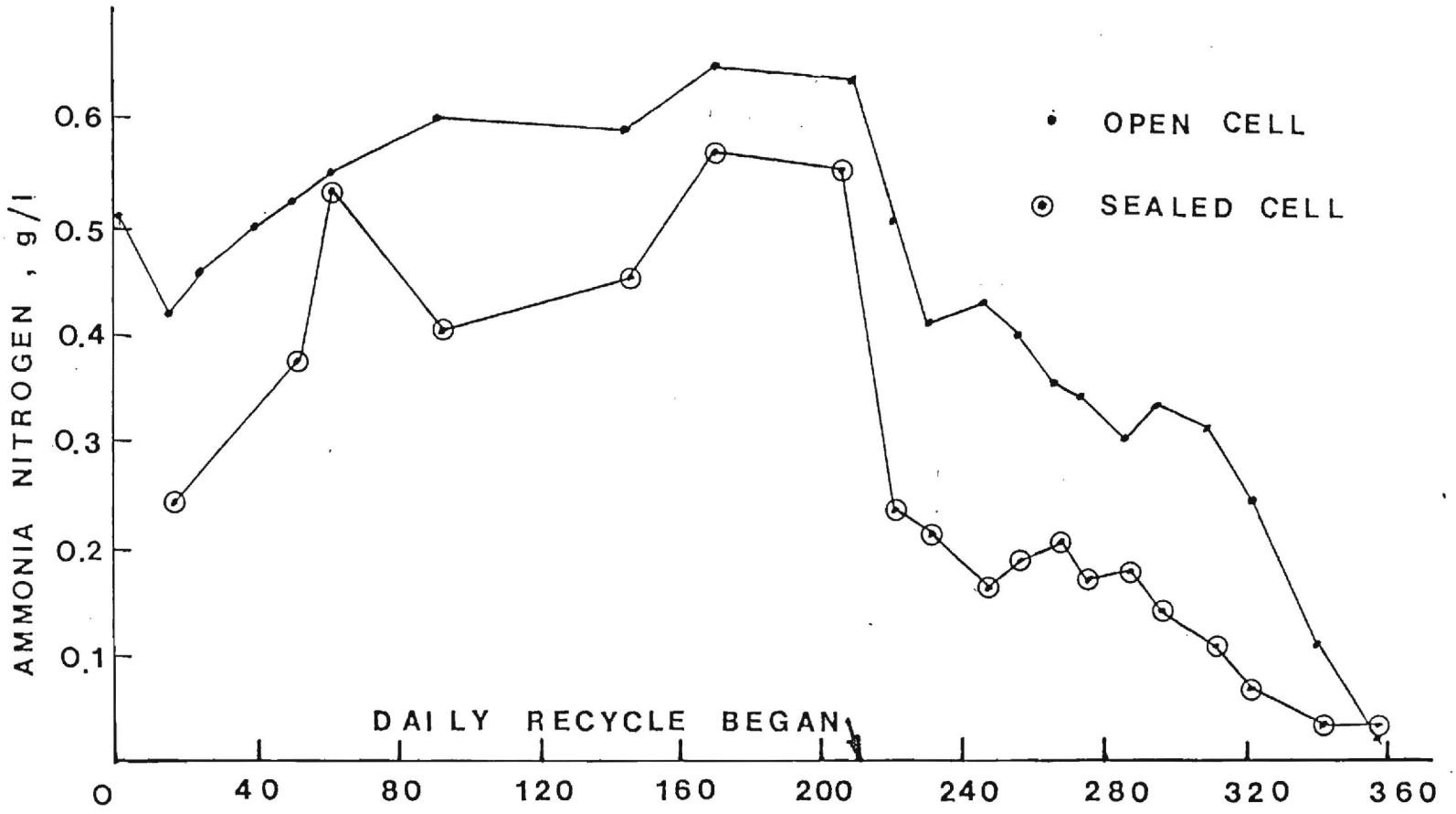
OXIDATION REDUCTION POTENTIAL OF LEACHATE



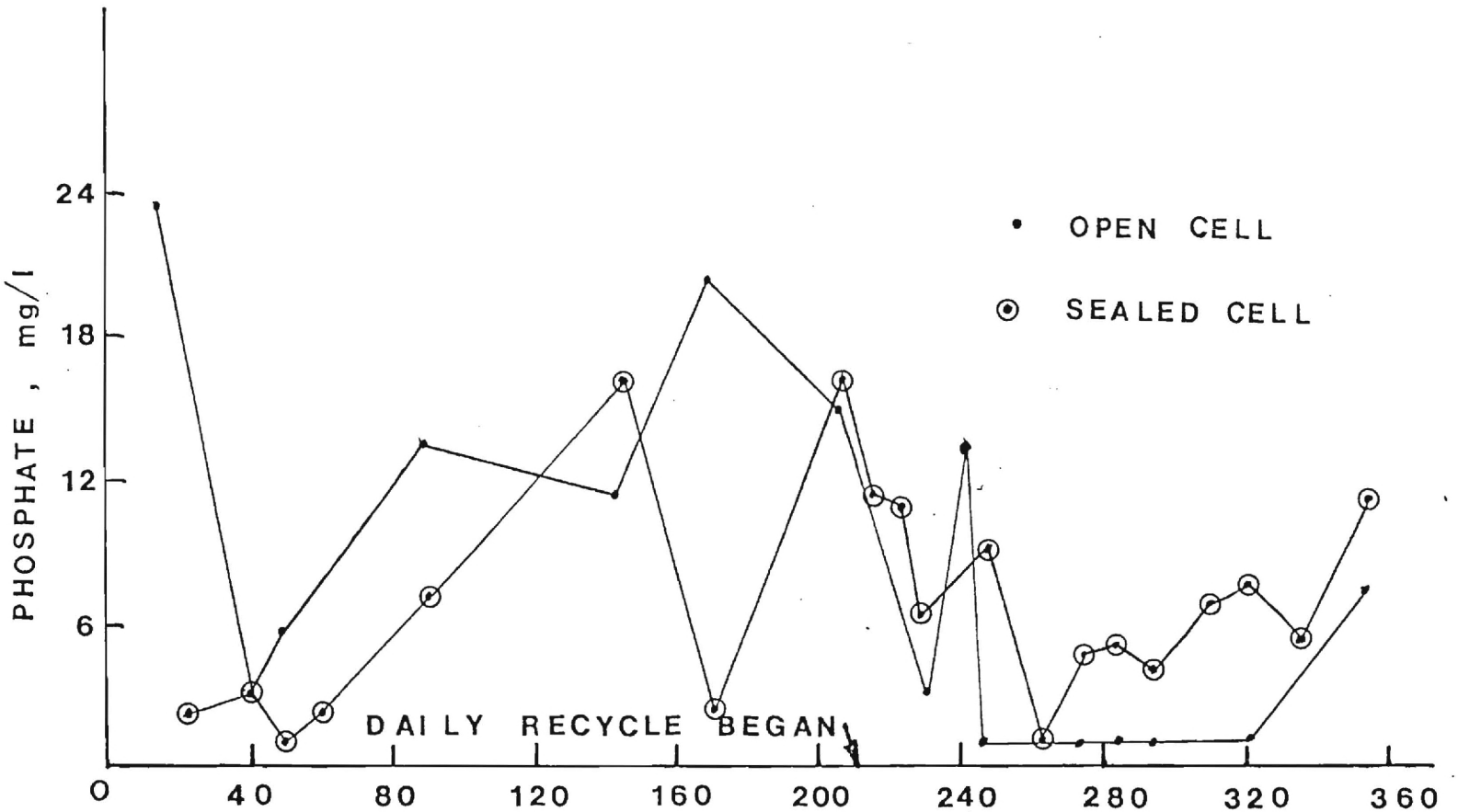
TOTAL SUSPENDED SOLIDS CONCENTRATION OF LEACHATE



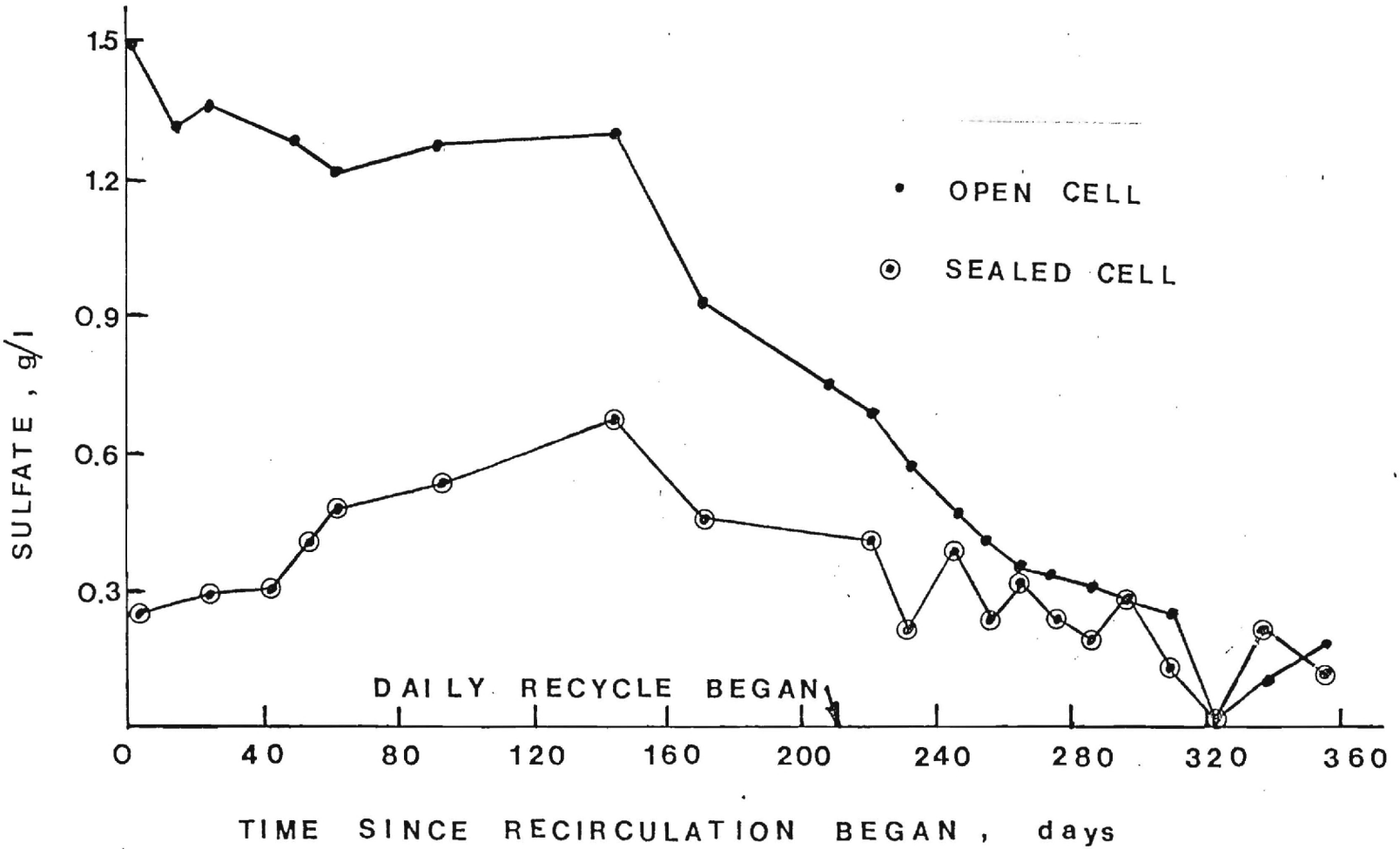
TOTAL KJELDAHL NITROGEN CONCENTRATION OF LEACHATE



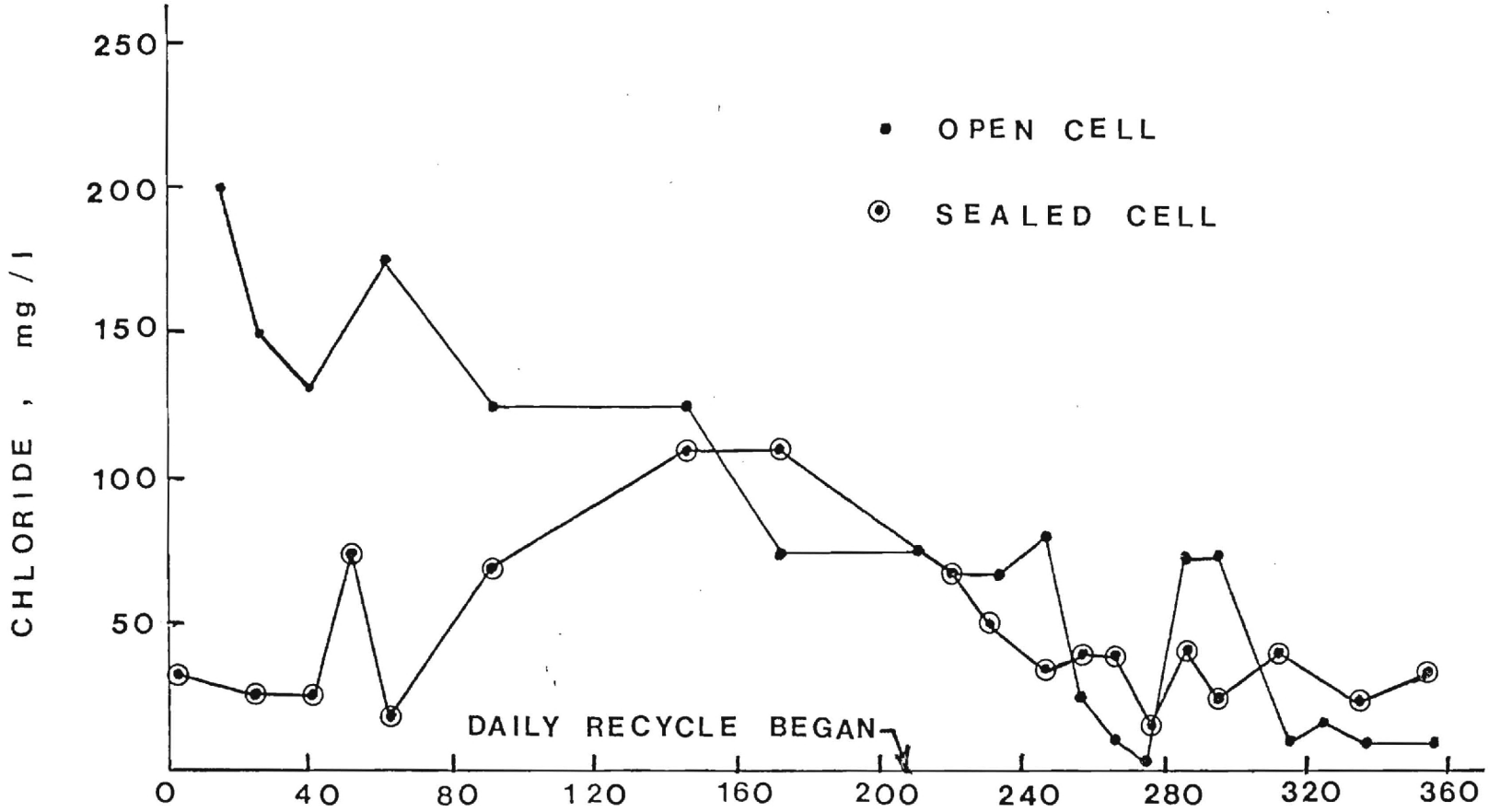
AMMONIA NITROGEN CONCENTRATION OF LEACHATE



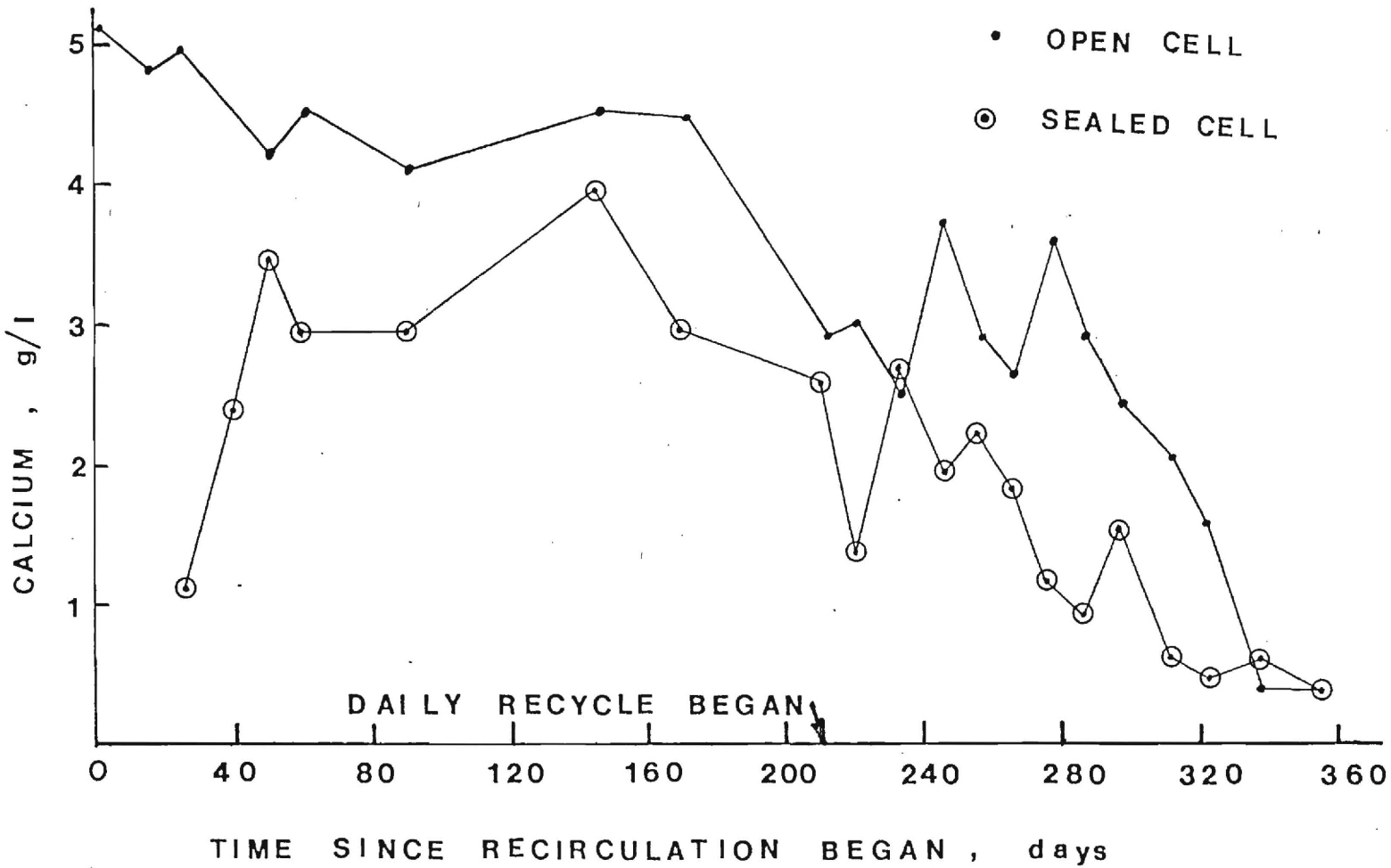
PHOSPHATE CONCENTRATION OF LEACHATE



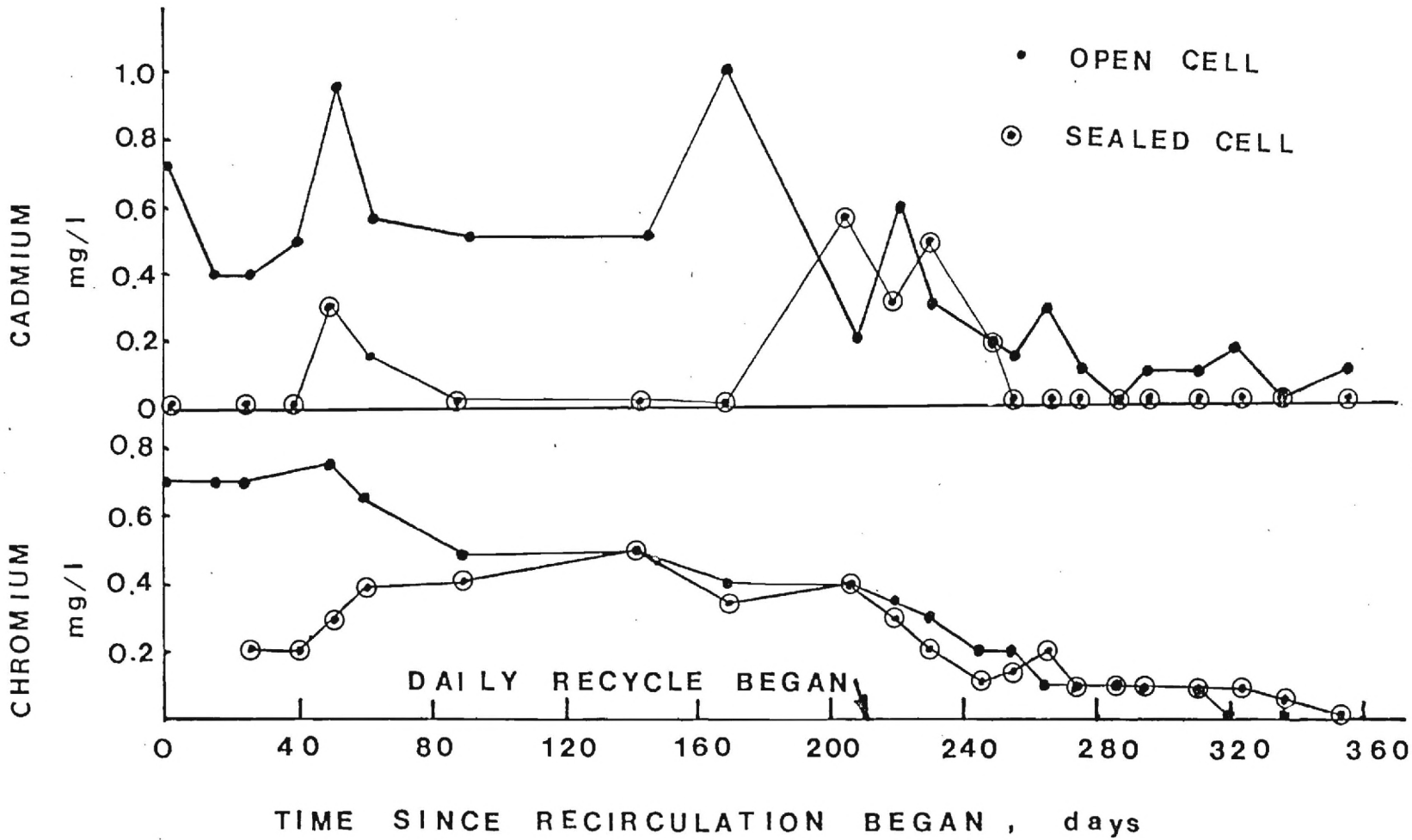
SULFATE CONCENTRATION OF LEACHATE



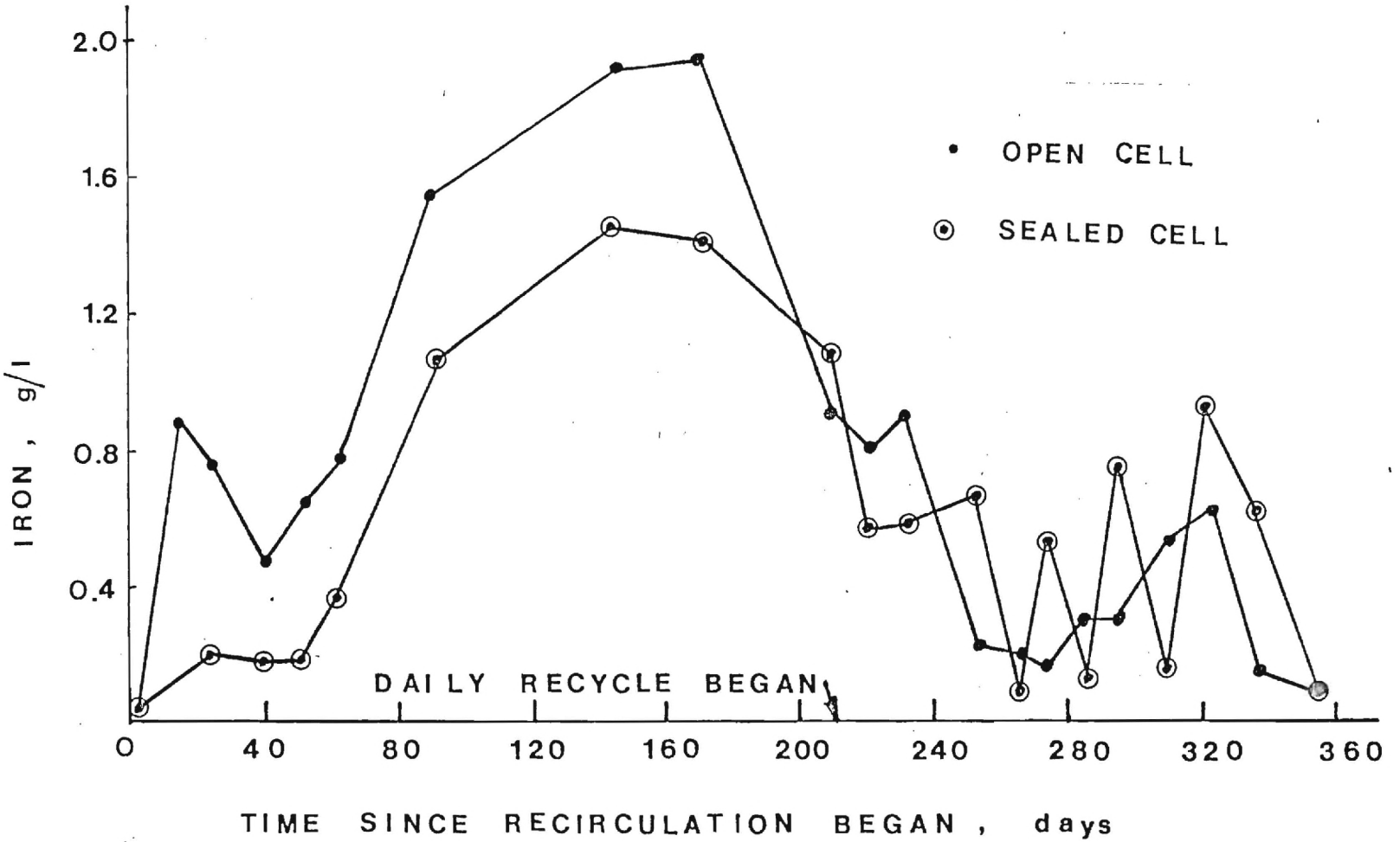
CHLORIDE CONCENTRATION OF LEACHATE



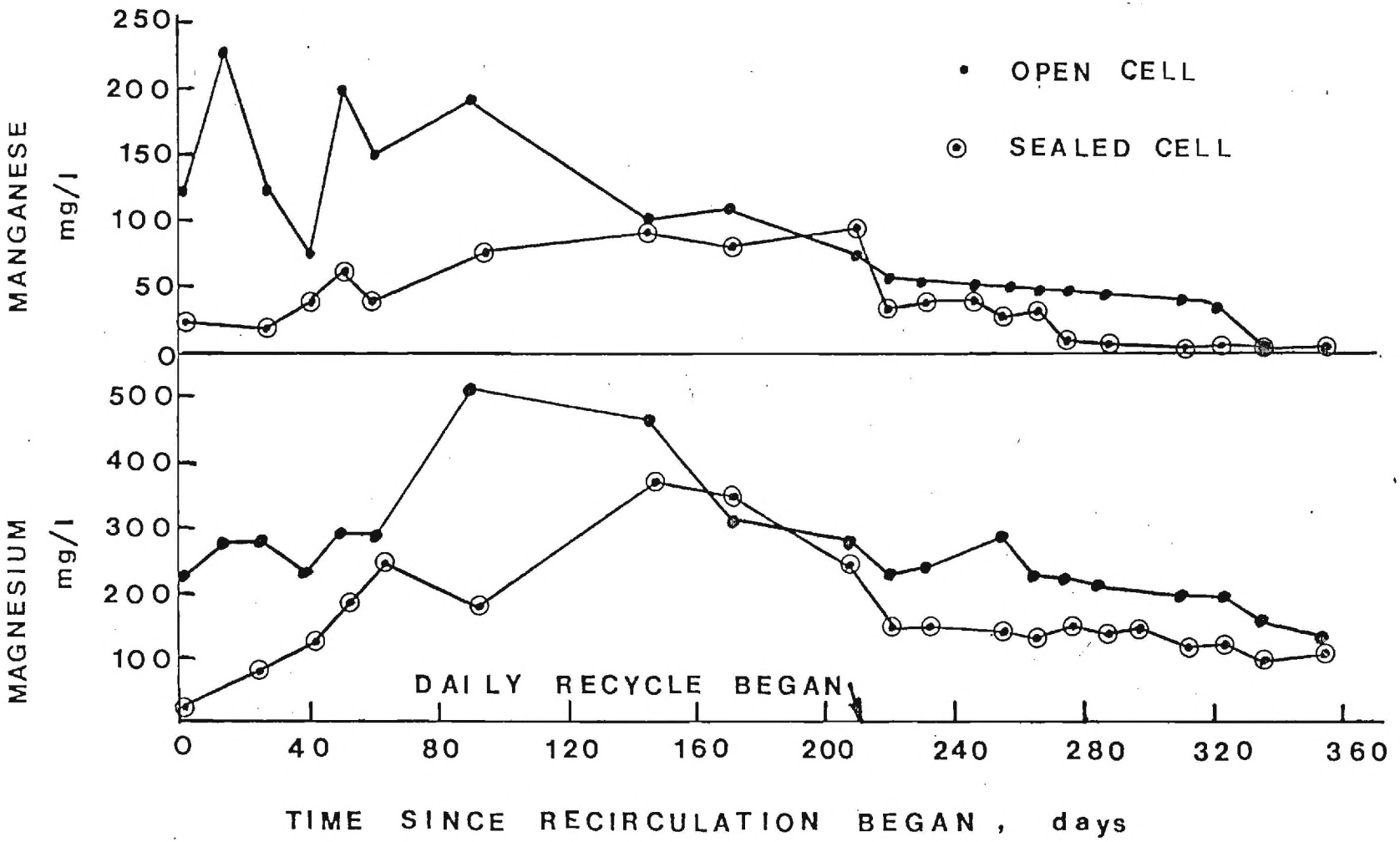
CALCIUM CONCENTRATION OF LEACHATE



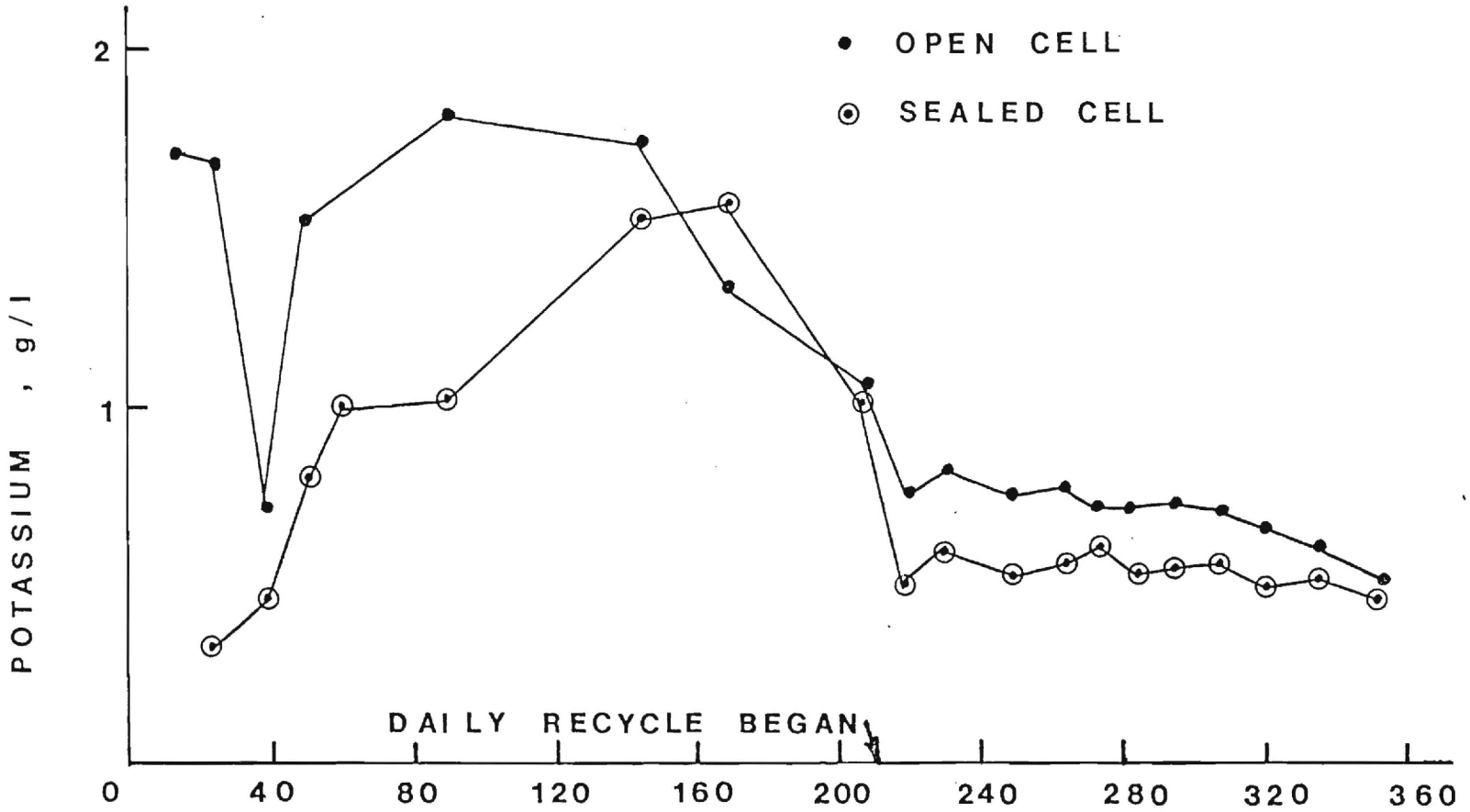
CADMIUM AND CHROMIUM CONCENTRATION OF LEACHATE



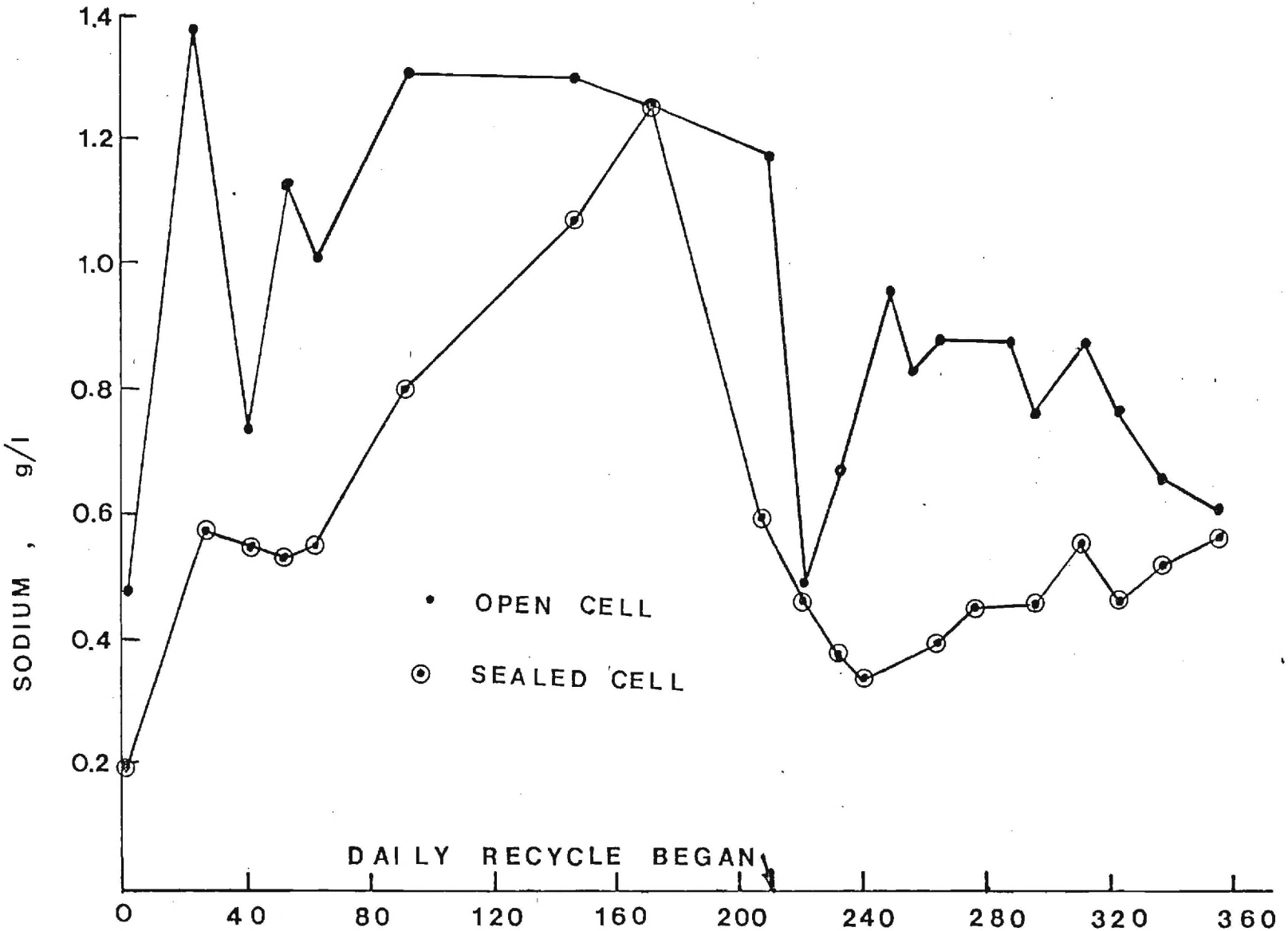
IRON CONCENTRATION OF LEACHATE



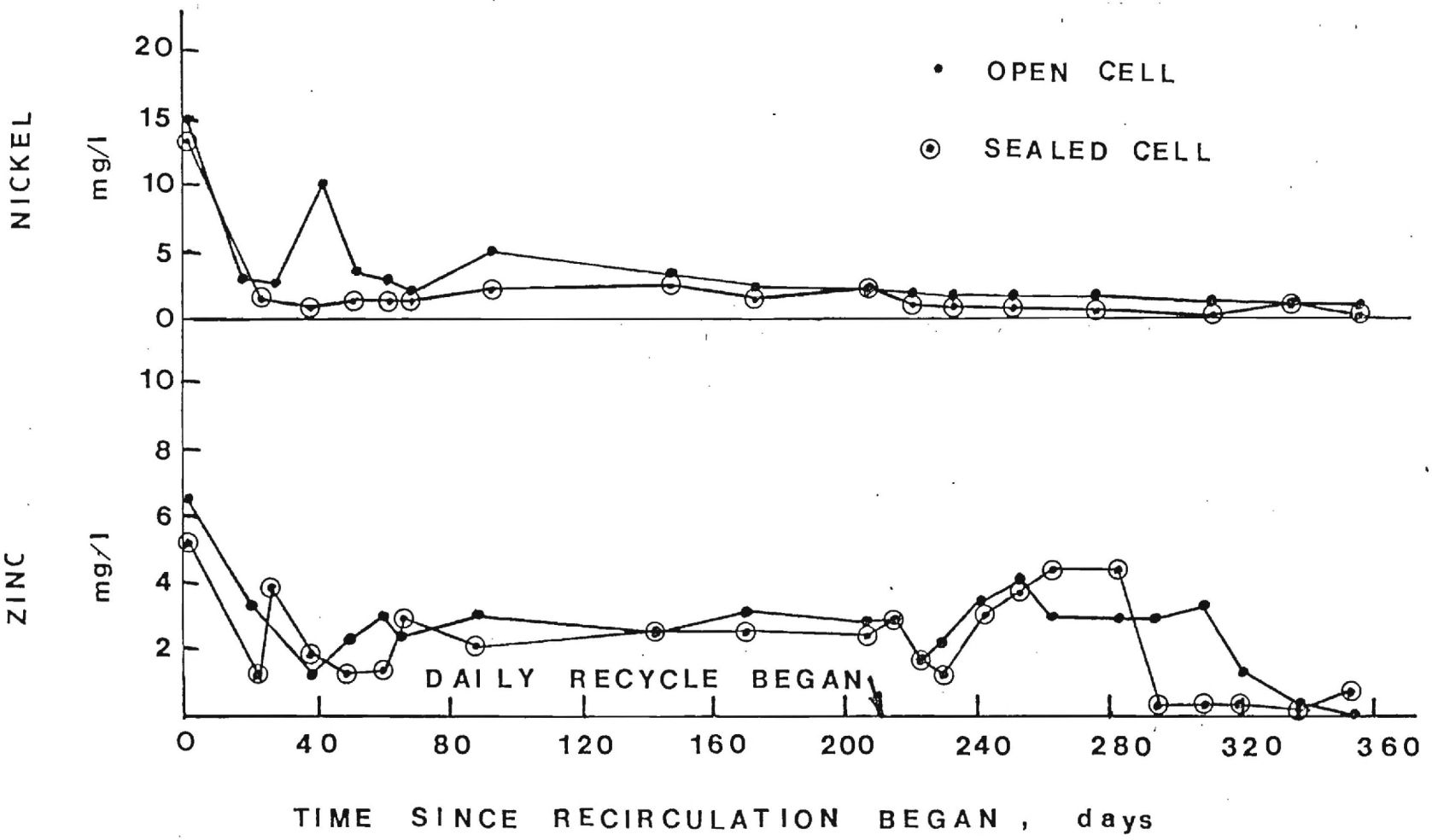
MANGANESE AND MAGNESIUM CONCENTRATION OF LEACHATE



POTASSIUM CONCENTRATION OF LEACHATE



SODIUM CONCENTRATION OF LEACHATE



NICKEL AND ZINC CONCENTRATION OF LEACHATE

The behavior of the pH and ORP will also influence these patterns since the microbially mediated stabilization processes as well as some of the potential physical-chemical interaction between the landfill mass and leachate constituents can be modified by the acid or basic and the oxidizing or reducing conditions prevailing. Accordingly, sulfate concentrations should be low or non-existent in the presence of low ORP which would also lead to enhanced viability of methane fermentation and probable precipitation/filtration within the landfill mass. Therefore, the measured concentrations of the various reactive metals would not only be a function of oxidation state but also the condition of pH and opportunity for physical interaction within the fill. This behavior should be more interpretable during the next project period as the overall process becomes more stable and tends toward more neutral pH and oxidizing conditions.

With the arrival of colder weather and an anticipated increase in rainfall, it may be necessary to provide for more insulation and different recycle schedules to preserve the overall continuity of the research investigation. Additional insulation has been added to avoid possible freezing problems and preliminary mass balance estimates are being developed. Contingency plans are also being formulated to allow for possible monitoring of the landfill cells beyond the termination date of the project should such a procedure be warranted. By January 1, 1979, a manuscript entitled "Pilot-Scale Investigations of Accelerated Landfill Stabilization with Leachate Containment and Recycle" will be prepared for presentation at an EPA-sponsored symposium scheduled for Orlando, Florida in March 1979.

Frederick G. Pohland
Project Director

E-20-614

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

March 6, 1979

TELEPHONE:
(404) 894-2265

Mr. Dirk Brunner, Project Manager
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Re: R-803953-02

Dear Dirk:

Included herewith are five copies of our 14th progress report on Project R-803953-02, "Controlled Landfill Stabilization by Leachate Recycle" (E-20-614) covering the period December 1, 1978 through February 28, 1979. I have updated and supplemented the data sent with out last report in preparation for preparation of our final report at the end of the next project period. As indicated in my request for a no-cost extension, we hope to establish whether or not the decreased stabilization rates observed during the winter months were influenced by lower temperatures.

We are anxiously awaiting your approval for continuation of our leachate recycle studies with the four rejuvented columns as described in our proposal (R-806498-01) and hope that such approval will be received in time to permit support of the project personnel without interruption. If there are any problems which would cause further delays, I trust you will contact me accordingly.

I plan to present the results of our efforts to date at the Orlando conference later this month and look forward to seeing you at that time.

Sincerely,

Frederick G. Pohland
Professor of Civil Engineering
Project Director

Enclosures
FGP:jp
cc: J. E. Fitzgerald, CE
Phyllis Oliver, OCA

xc: file, E-20-614
cys to Al Becker

Quarterly Progress Report No. 14

"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-8039353-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
December 1, 1978-March 28, 1979

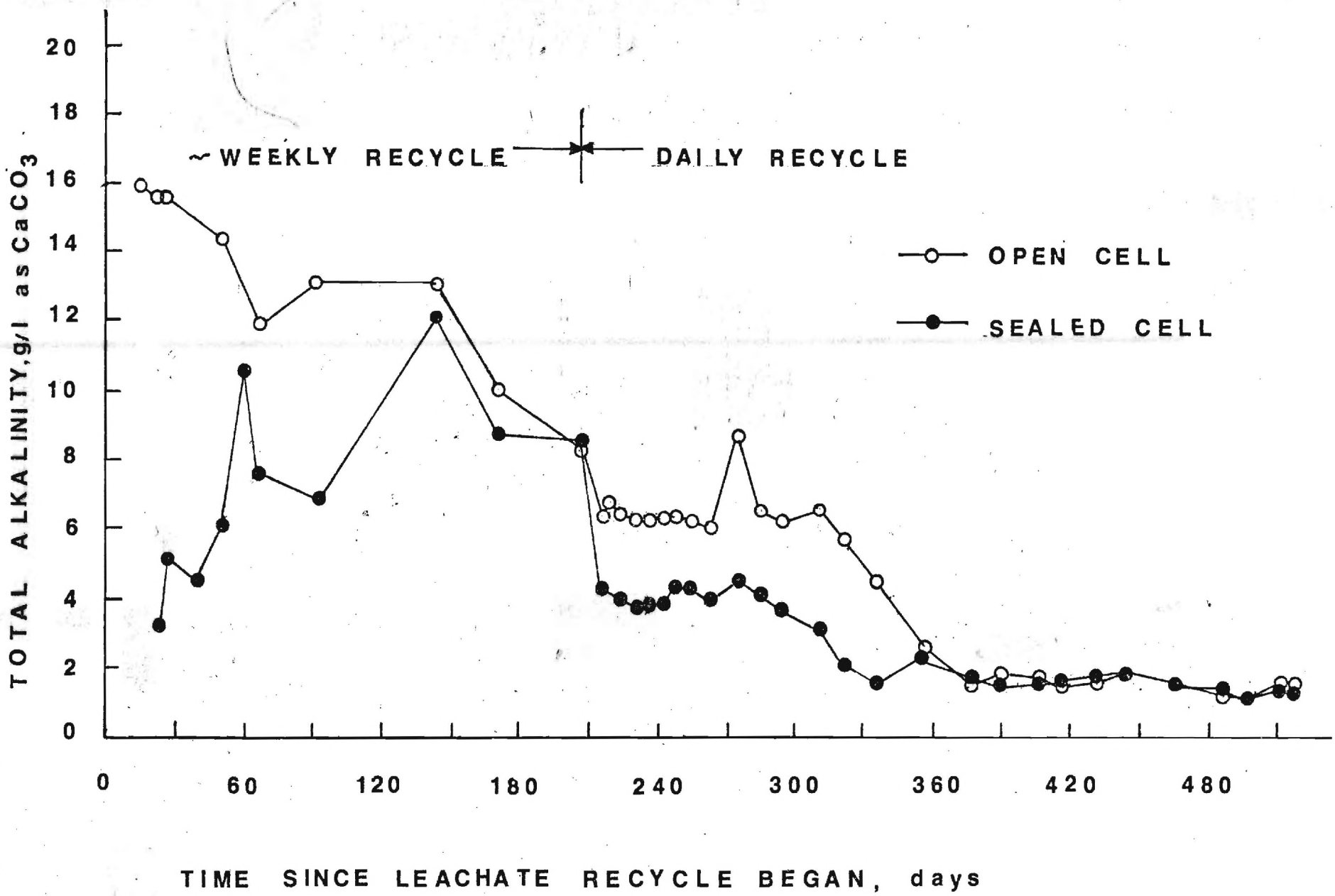
The results obtained during this report period continue to reflect anticipated stabilization patterns with leachate recycle through the experimental landfills. Increased precipitation and colder weather have been experienced; their total impact has yet to be determined with respect to possible decreases in stabilization rates or effects on dilution. It is believed, however, that the majority of the readily available organic material in the solid waste mass has been depleted as a consequence of recycle.

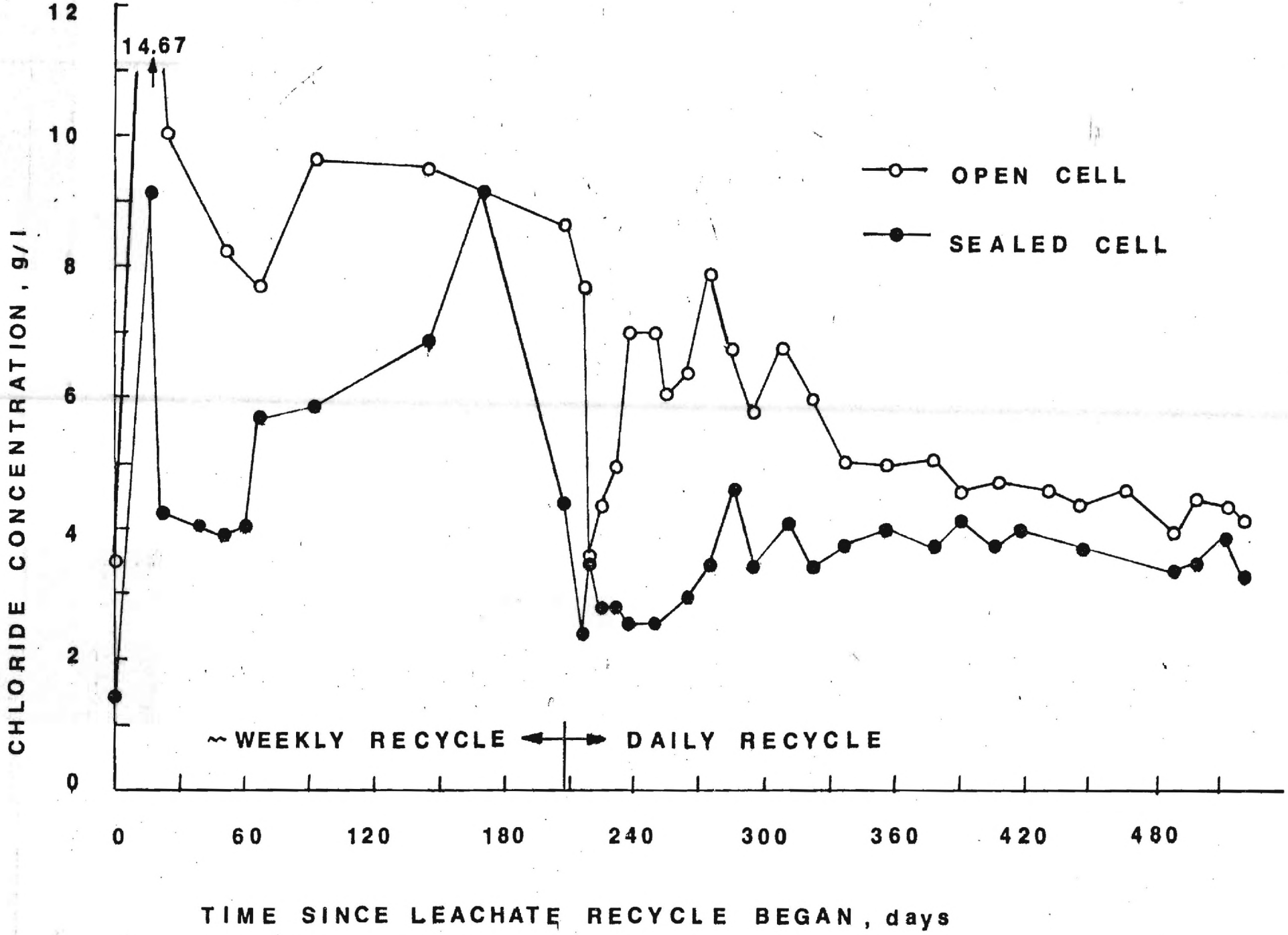
Monitoring for indicator parameters has continued throughout the report period with an overall decrease to minimal concentrations for chemical constituents. The associated biological activity also has diminished as reflected by a veritable disappearance of volatile acids and a tapering off of gas production. This elimination in measurable volatile acid concentrations has also caused a concomitant rise in pH in both cells as indicated on the attached figures. The concentrations of BOD and COD have responded similarly, but concentrations are still sufficiently high to suggest some continued stabilization during the following project period.

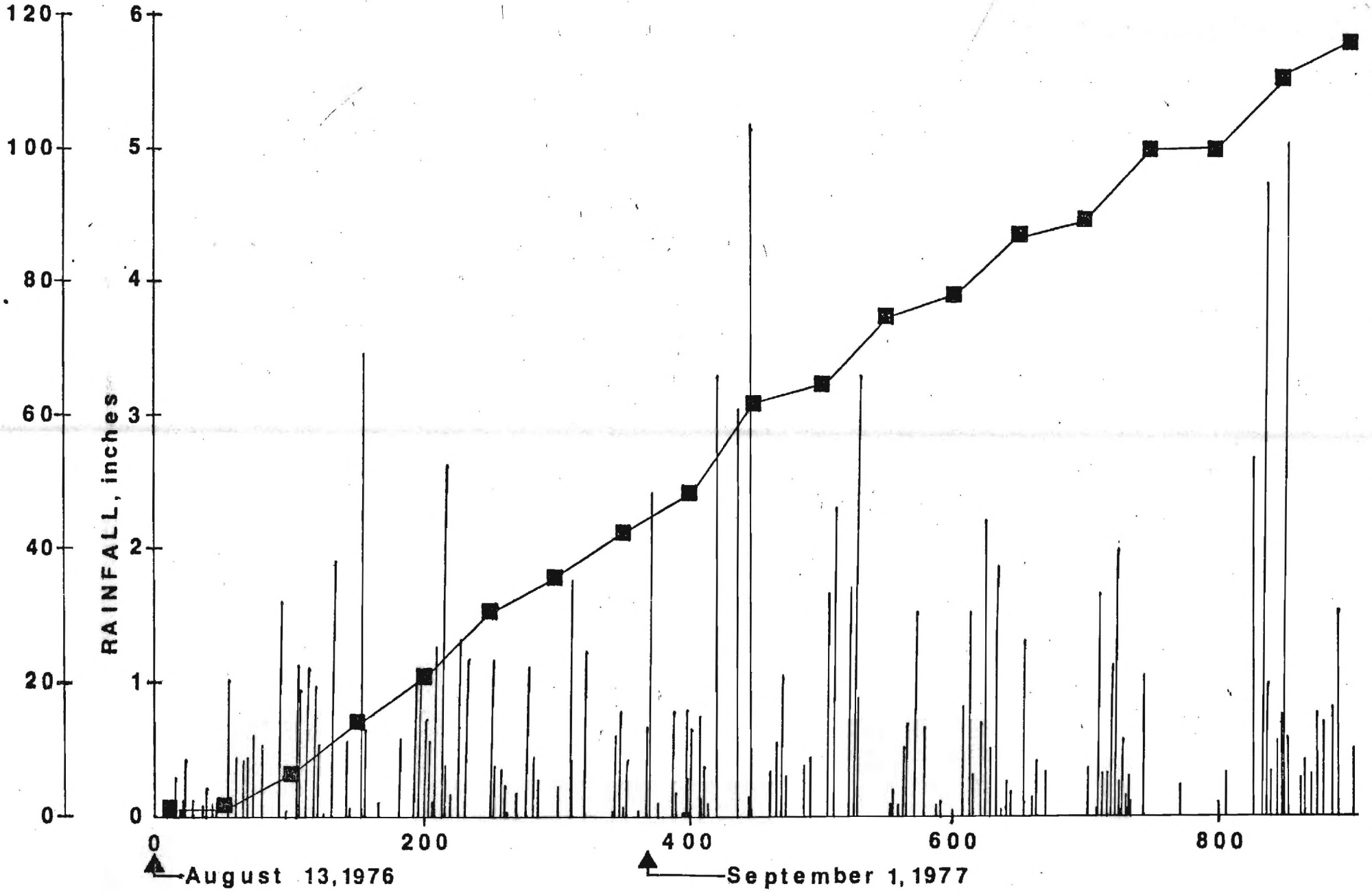
Conservative substances such as chlorides have become constant in concentration, changing only as dilution takes its effect. Differences between the open and sealed cell are indicative of variations due to evaporation and will be used together with measurements of total liquid remaining at the end of the project to determine mass fluxes of constituents.

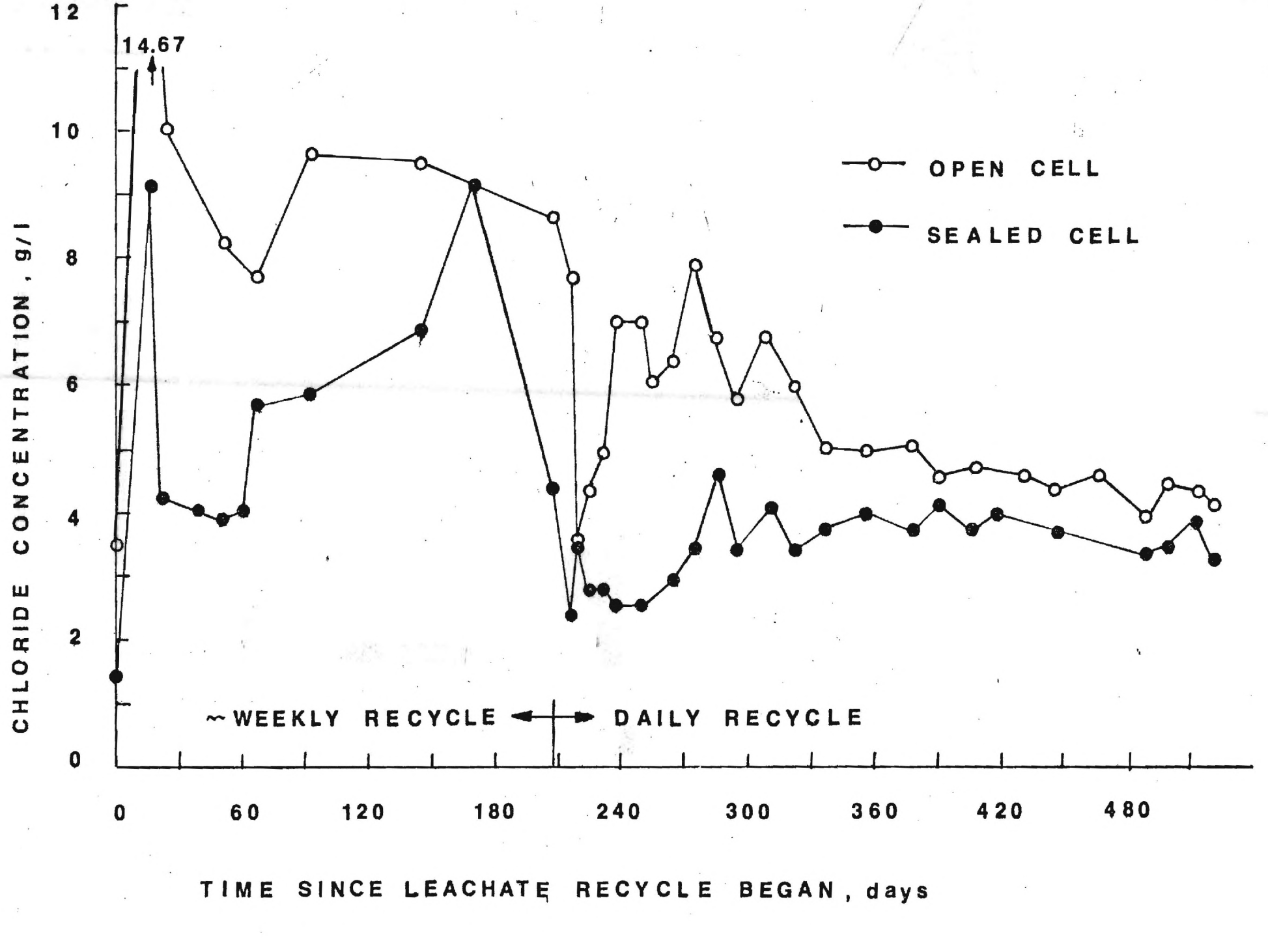
Other parameters not included in the attached figures have followed trends similar to those reported in preceding project reports. These will be updated and included in the final report as well as presented at the Orlando SHWRD Research Symposium on March 26-28, 1979. It is anticipated that continued monitoring of the leachate and gas production from the simulated landfills during the next project period will permit final determination of gas production and evaporation potential as originally planned as major project objectives at the onset of the project.

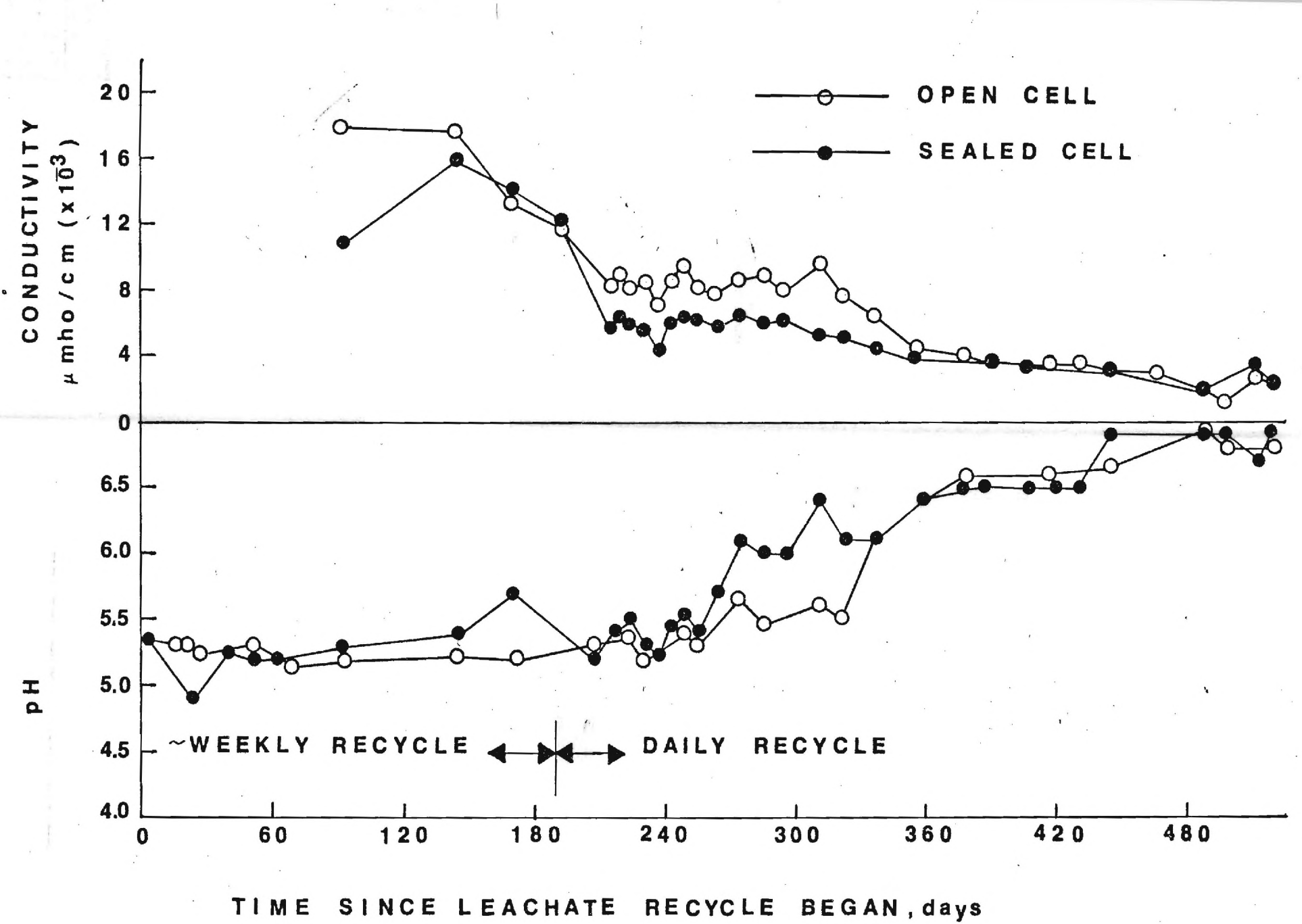
Frederick G. Pohland
Project Director

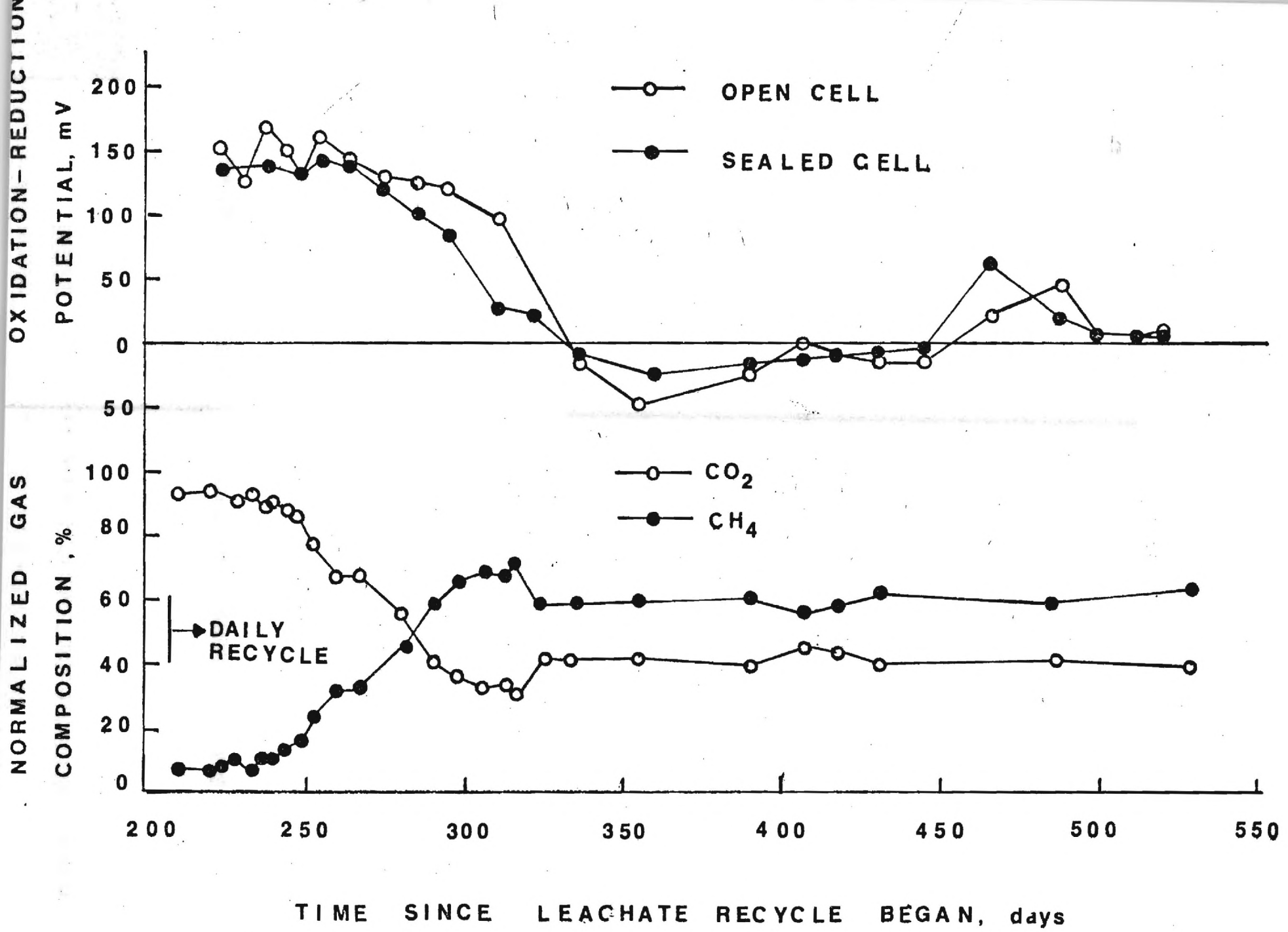

~WEEKLY RECYCLE
DAILY RECYCLE
OPEN CELL
SEALED CELL
TOTAL ALKALINITY, g/l as $CaCO_3$
0
2
4
6
8
10
12
14
16
18
20
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days

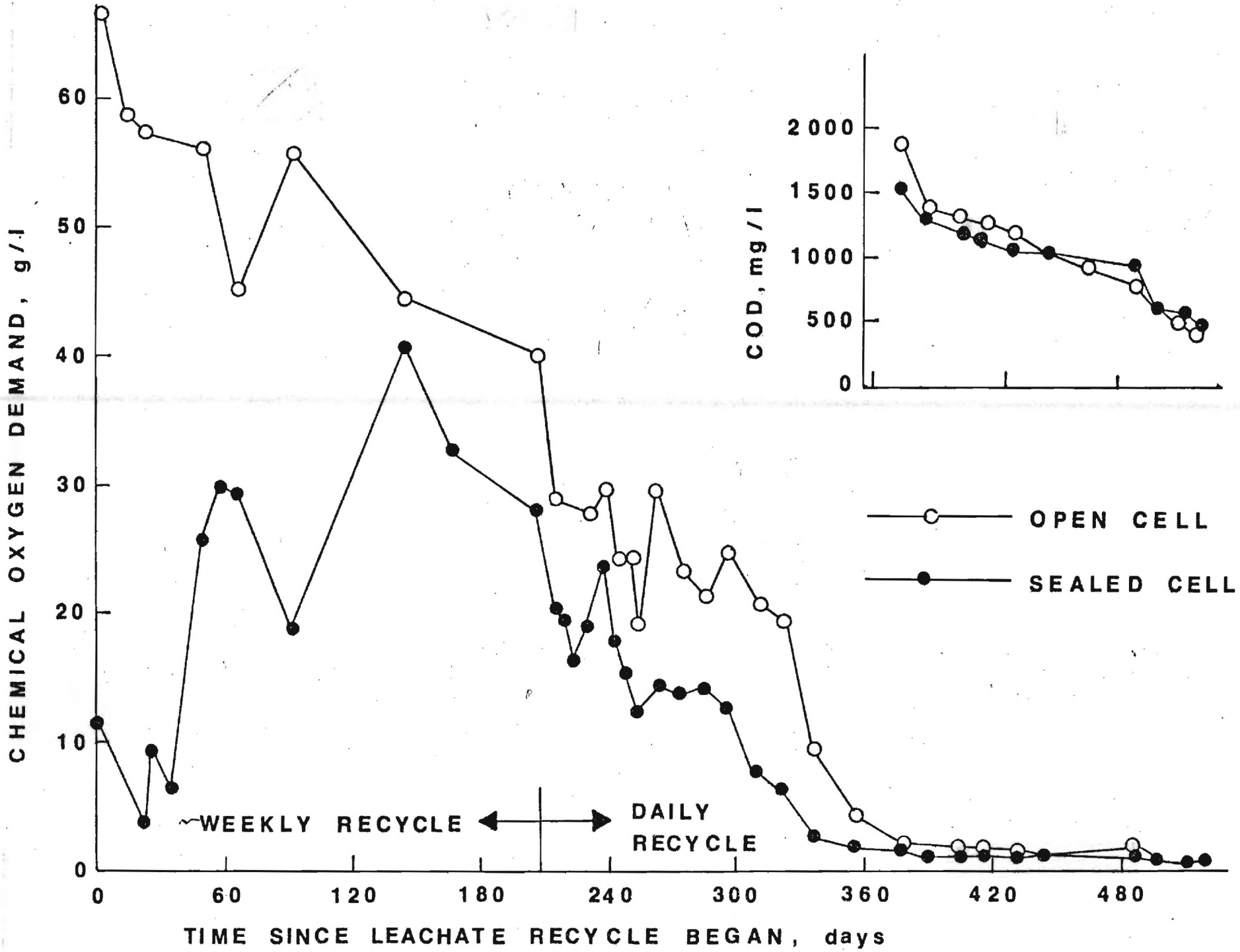

12
14.67
10
8
6
4
2
0
CHLORIDE CONCENTRATION, g/l
OPEN CELL
SEALED CELL
~WEEKLY RECYCLE
DAILY RECYCLE
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days

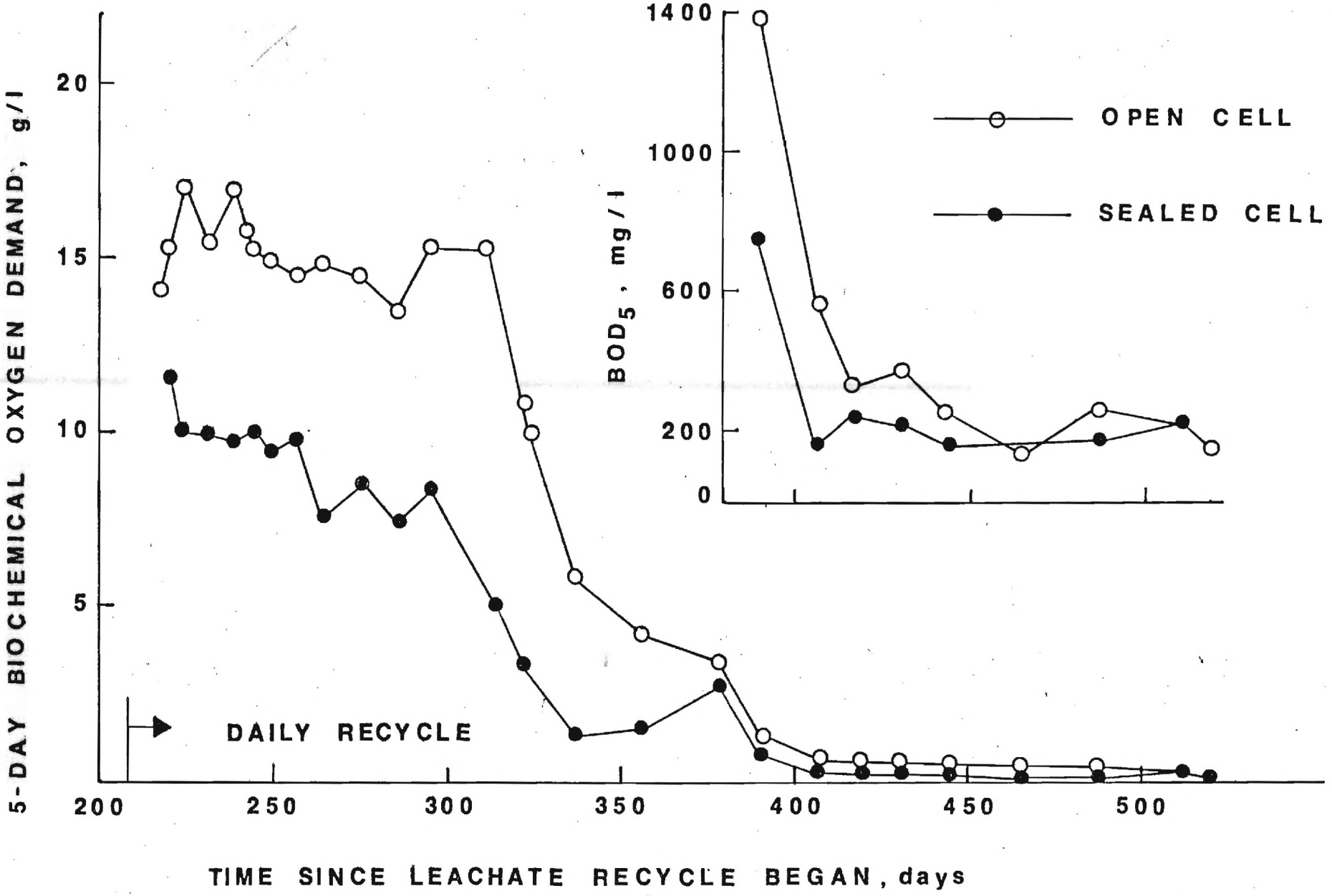

120
100
80
60
40
20
0
6
5
4
3
2
1
0
RAINFALL, inches
0
200
400
600
800
August 13, 1976
September 1, 1977
TIME SINCE PLACEMENT OF SOLID WASTE, days

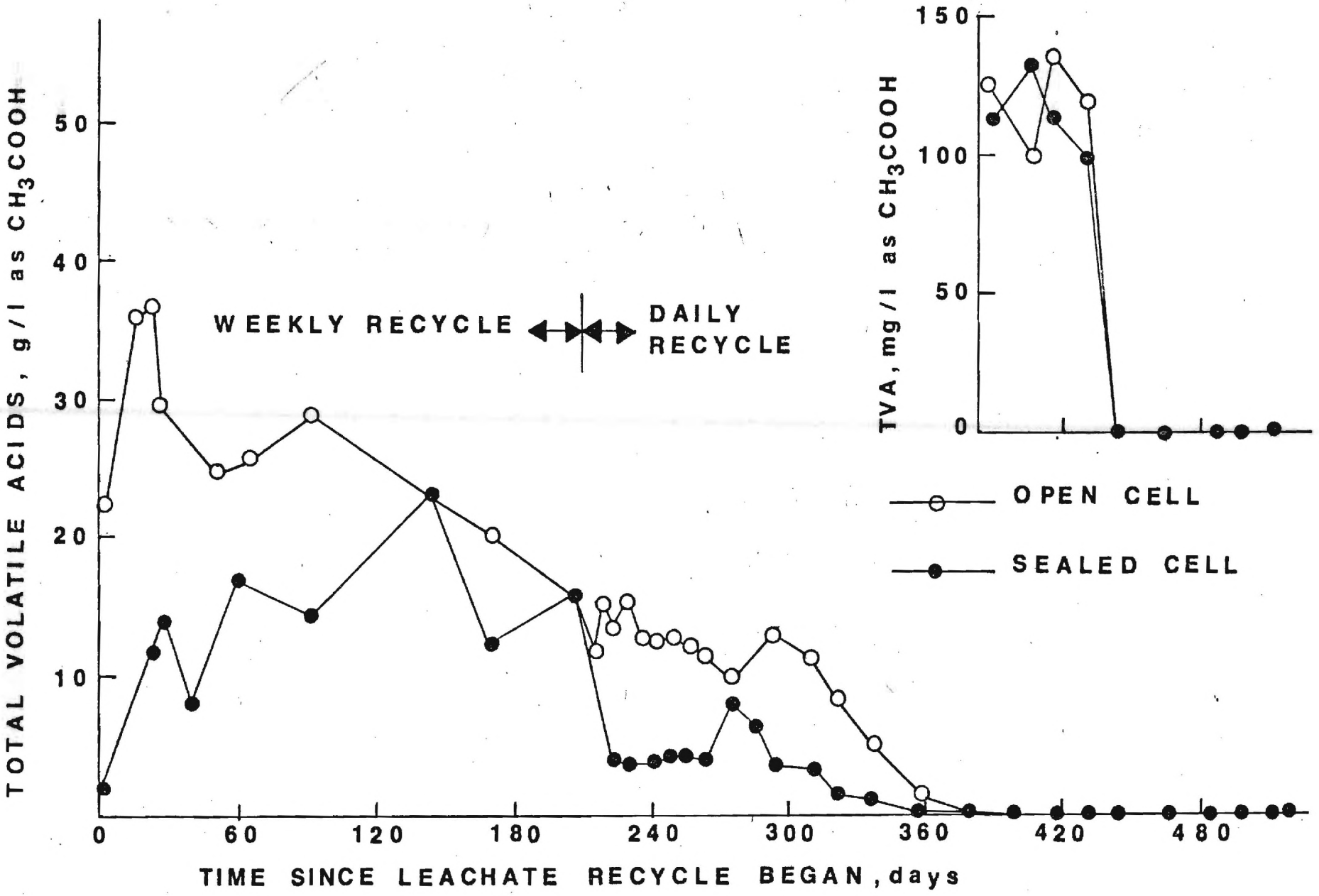

12
10
8
6
4
2
0
14.67
CHLORIDE CONCENTRATION, g/l
OPEN CELL
SEALED CELL
~WEEKLY RECYCLE
DAILY RECYCLE
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days

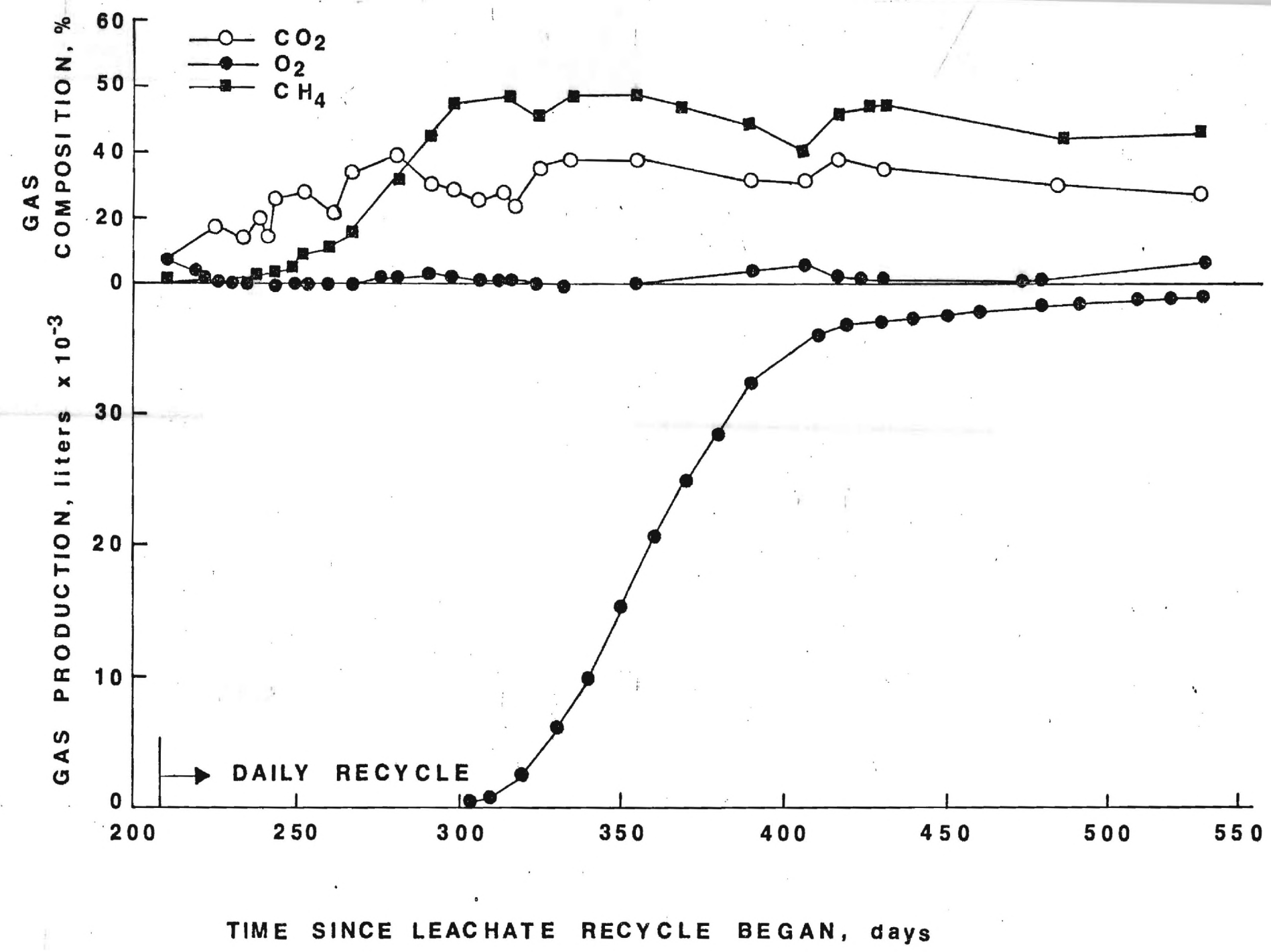

CONDUCTIVITY
μ mho/cm (x10⁻³)
20
16
12
8
4
0
OPEN CELL
SEALED CELL
pH
6.5
6.0
5.5
5.0
4.5
4.0
~WEEKLY RECYCLE
DAILY RECYCLE
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days


OXIDATION-REDUCTION POTENTIAL, mV
200
150
100
50
0
50
OPEN CELL
SEALED CELL
NORMALIZED GAS COMPOSITION, %
100
80
60
40
20
0
CO_2
CH_4
DAILY RECYCLE
200
250
300
350
400
450
500
550
TIME SINCE LEACHATE RECYCLE BEGAN, days


CHEMICAL OXYGEN DEMAND, g/l
0
10
20
30
40
50
60
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days
WEEKLY RECYCLE
DAILY RECYCLE
OPEN CELL
SEALED CELL
COD, mg/l
0
500
1000
1500
2000


5-DAY BIOCHEMICAL OXYGEN DEMAND, g/l
20
15
10
5
200
250
300
350
400
450
500
DAILY RECYCLE
TIME SINCE LEACHATE RECYCLE BEGAN, days
1400
1000
600
200
0
BOD_5, mg/l
OPEN CELL
SEALED CELL


TOTAL VOLATILE ACIDS, g/l as CH_3COOH
50
40
30
20
10
WEEKLY RECYCLE
DAILY RECYCLE
0
60
120
180
240
300
360
420
480
TIME SINCE LEACHATE RECYCLE BEGAN, days
TVA, mg/l as CH_3COOH
150
100
50
0
OPEN CELL
SEALED CELL


GAS COMPOSITION, %
60
50
40
20
0
CO_2
O_2
CH_4
GAS PRODUCTION, liters x 10^{-3}
30
20
10
0
DAILY RECYCLE
200
250
300
350
400
450
500
550
TIME SINCE LEACHATE RECYCLE BEGAN, days

Quarterly Progress Report No. 15

"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant NO. R-8039353-02
Research Project E-20-614
Georgia Institute of Technology
Atlanta, Georgia
April 1, 1979 - June 30, 1979

The results obtained during this report period extend those data presented previously and can be compared with the last reporting period as follows:

	Day 521 (Feb. 3, 1979)		Day 660 (June 7, 1979)	
	Open cell	Sealed Cell	Open Cell	Sealed Cell
Total Alkalinity, mg/l $CaCO_3$	1628	1440	1669	1666
Chloride, mg/l	410	323	200	175
Conductivity, μmho/cm	2325	2675	1360	1330
pH	6.8	7.0	6.7	6.6
ORP, mV	-94	-95	-111	-111
COD, mg/l	469	473	411	410
BOD_5, mg/l	160	155	111	88
Total Volatile Acids, mg/l HAc	ND	ND	ND	ND
TKN, mg/l N	52	52	28	30
NH_3-N, mg/l N	30	34	12	13
Total Phosphorus, mg/l $PO_4^{\equiv}$	0.6	1.4	-	-

ND = none detectable

Although the data indicated a leveling trend in concentrations of constituents in the leachate, simulated rainfall is not being added to the sealed cell because of space limitations so that with that addition, concentrations at least in the sealed cell would tend to be more dilute than indicated. Since April 10, 1979, these additions have been discontinued and the quantity of simulated rainfall normally to have been added to the sealed cell is approaching 1000 gallons. Moreover, ambient temperatures have only recently neared the highs recorded last year which may initiate a recurrence of more active biological activity and removal of remaining biological decomposable residuals in the leachate. The next project period should shed some light on this area of the investigation.

No measurable gas is being produced by the closed cell although some biologically oxidizable material remains and conditions (ORP, pH, etc.) appear to remain favorable for methane fermentation. The integrity of the sealed cell has been checked without indicating gas leaks and no gas has flowed through the gas measuring apparatus since the last report period. Moreover, the composition of gas sampled from within the closed cell remains at CH_4:CO_2 of about 60:40 previously reported.

Since organic pollutants as measured by COD and BOD_5 appear to be lingering in the leachate, present efforts are being directed at determining whether

some of this residual is immediate demand due to the reducing environment that remains in both cells. Therefore, both BOD_5 and COD analyses are being conducted with and without initial aeration of samples until the reducing conditions have been displaced. The results of these analyses will be reported after the present project period has been completed.

During the next project period, observations will be made to determine whether the onset of high temperatures will reestablish more active biological activity within the cells and to ascertain the quantity of waterand rainfall equivalent contained in the respective open and sealed cells. Studies will also be initiated on single pass flow after draining in the open cell. The sealed cell will be monitored in its present operating mode until both cells are drained and then allowed to remain dormant for two months before single pass leaching of rainfall equivalent is permitted to commence. Whether or not these studies will be carried to completion will be a function of receipt of extended funding through October 1979 as requested; if funding is received, a scan for residual concentrations in the leachate will also be performed.

A portion of the results of progress to date will be reported at the ASCE National Conference on Environmental Engineering in San Francisco, July 9-11, 1979.

Frederick G. Pohland
Project Director

Quarterly Progress Report No. 16
"Controlled Landfill Stabilization by Leachate Recycle"
EPA Grant No. R-8039353-02
Research Project No. E-20-614
Georgia Institute of Technology
Atlanta, Georgia
July 1, 1979-September 30, 1979

During this phase of the project, additional samples and analyses during leachate recycle yielded the following data with respect to those reported in the last progress report:

	Day 660 (June 7, 1979)		Day 699 (July 16, 1979)	
	Open Cell	Sealed Cell	Open Cell	Sealed Cell
Total Alkalinity, mg/l $CaCO_3$	1669	1666	1338	1620
Chloride, mg/l	200	175	178	165
Conductivity, μmho/cm	1360	1330	1080	1100
pH	6.7	6.6	6.7	6.7
ORP, mV	-111	-111	-91	-81
COD, mg/l	411	410	350	360
BOD_5, mg/l	111	88	88	80
Total Volatile Acids, mg/l HAc	ND	ND	ND	ND
TKN, mg/l N	28	30	20	25
NH_3-N, mg/l N	12	13	9	9
Total Phosphorus, mg/l $PO_4^{\equiv}$	0.6	1.4	0.8	1.2

ND = non detectable

These data again indicated a leveling trend for most parameters without any accelerated activity by increasing temperatures during the warmer summer months. Differences in concentration between the open and sealed cells can again be attributed to the discontinuation of moisture addition to the sealed cell (since April 10, 1979) and the opportunity for some dilution potential loss in the open cell due to evaporation of some of the rainfall. The higher temperatures ($\sim$38°C) again experienced did not initiate a recurrence of more active biological activity although some BOD_5 tended to linger in the leachate and was not removed anaerobically with gas production. Separate analyses of leachate samples with and without addition of BOD nutrients in a respirometer indicated a nutrient deficiency in the leachate attributable possibly to low phosphorus concentrations. Therefore, it is likely that phosphorus may be the limiting nutrient for anaerobic stabilization of leachate within a landfill environment.

On day 699, leachate recycle was terminated in each cell and the cells were permitted to drain. This process of draining, once beyond the initial discharges, has become very slow and indicates a possible moisture capture within the landfill mass probably enhanced by the use of shredded refuse.

This observation somewhat curtails an estimate of total pollutant flux since the extent of the moisture reservoir in each cell is difficult to ascertain at this point. Moreover, rainfall onto the open cell without any additional water added to the sealed cell makes direct comparison uncertain. Therefore, it is intended to permit drainage to continue until liquid discharges become inconsequential. At this point both the open and sealed cells will receive rainfall or rainfall equivalent; the latter to determine whether the absence of moisture addition for a period of time will lead to a more concentrated discharge when again exposed to the influx of moisture.

Leachate samples are continuing to be collected periodically from both cells and will be subjected to routine as well as special analyses for residual and refractory compounds. Unfortunately, some analytical difficulty has been encountered with the instruments used for these latter analyses which is being resolved at the present time. This delay coupled with the delay consequenced by the slow drainage of the cells has placed the projected work off schedule. It is intended to accommodate this delay by a request for a no cost, 2-month extension of the project period to December 31, 1979.

A portion of the results of progress to date has been accepted as part of an international seminar on sanitary landfills held in Berlin, October 3-5, 1979.

Frederick G. Pohland
Project Director

Project Summary

CONTROLLED LANDFILL STABILIZATION BY LEACHATE RECYCLE

Frederick G. Pohland

This research project on the use of leachate containment, collection and recycle through a simulated pilot-scale landfill containing shredded municipal solid wastes was initiated to further establish the relative merits and potential applicability of this landfill management option in engineering practice and to thereby overcome some of the difficulties attendant with the separate leachate and gas treatment and control systems being used at the present time.

To accomplish the goals of the research endeavor, two simulated landfill cells, 3.5 m on each side and with a depth of 4.27 m were constructed and equipped with a containment liners underdrain systems, leachate reservoirs and recycle appurtenances for collection and distribution of leachate back through the solid waste mass, and provisions for gas collection and measurement. One of the cells was constructed with a liner at the surface to seal the contents within and augment gas collection opportunities; the other remained open to the atmosphere to permit the introduction of incident rainfall and the determination of infiltration and/or evaporaton. This open cell was allowed to reach apparent field capacity, at which time leachate recycle was commenced. The sealed cell received moisture equivalent to incident rainfall by the addition of tap water so that recycle could be initiated in each cell at the same time.

After recycle was commenced, routine analyses were performed on the leachate and gas over a period of about three years, followed by additional investigations on solid waste and leachate characteristics after accelerated stabilization of the readily available organic leachate constituents had been completed. Removal efficiencies of greater than 99% were observed for the organic pollutants in the leachate, with the majority of this removal occurring within a relatively short 6-month period. Greatest gas yields corresponded to the highest rates of stabilization and most of the gas was produced during an even shorter period of about three months.

The extent of evaporation of moisture from the open cell depended upon seasonal and meteorological conditions and varied between 19 and 39%. These variations were shown to affect concentration and volume determinations necessary to calculate the relative masses of leachate constituents with time. Preliminary functional group and priority pollutant analyses indicated the probable role of complexaton in mobilizing metal species and the origin and significance of refractory compounds, respectively. Cost comparisons with

other separate leachate treatment systems emphasized the economic advantage of leachate recycle as an attractive and innovative landfill management alternative.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Regulations governing land disposal of wastes require safeguards against migration of reaction products into the environment. Much of this emphasis is due to concern over the consequences of leachate and gas production which are inextricably related and, therefore, tend to manifest themselves in an often unpredictable and elusive fashion. Moreover, detrimental environmental impacts of leachate and gas migration from landfills are frequently evaluated only after the fact and without much opportunity for immediate and lasting remedy. This dilemma is a direct outgrowth of past landfill management practices and a tradition of presuming isolation of landfill sites and storage of their contents in perpetuity.

From an engineering point of view, positive operational control over landfill disposal of wastes can provide necessary guarantees against environmental impairment. Therefore, the concepts of confinement of the site and/or control of the reaction products within the site become applicable as logical and technically sound management options, particularly in sensitive groundwater quality areas. However, implicit in the concept of confinement is a requirement for isolation, accumulation, collection, and regulated treatment or release of contaminants.

In recognition of the possible need for collection and treatment of leachate at certain landfill sites, numerous investigations have been conducted to evaluate the relative propriety of both biological and physical-chemical treatment methods. These efforts collectively indicate that preparations for separate leachate treatment, except possibly for simple storage or regulated discharge to an existing sewerage system, become exceedingly challenging and fraught with difficulties particularly when the unpredictability and variability of leachate production and quality with time are considered. Moreover, since measurable leachate production, without the intentional addition of moisture to the landfill either during operation or after closure, is generally delayed for an indeterminate number of years, separate treatment becomes an *ex post facto* proposition and eventual implementation and its effectiveness can only be a matter of conjecture.

To alleviate some of these problems and to more directly address the issues of control and predictability of landfill behavior, the concept of leachate containment, collection and recycle utilizing the landfill as an *in situ* biological and physical-chemical treatment system was conceived and this report details the results of the most recent effort.

Experimental Approach

Two pilot-scale landfill cells, 4.27 m deep and 3.05 m on a side, were constructed with the operational features indicated in Figure 1. One cell was left open to incident rainfall; the other was eventually sealed to allow for gas collection and to prohibit loss of moisture by evaporation. Accordingly, the amounts of rainfall received by the open cell could be matched by an equivalent amount of tap water added to the sealed cell.

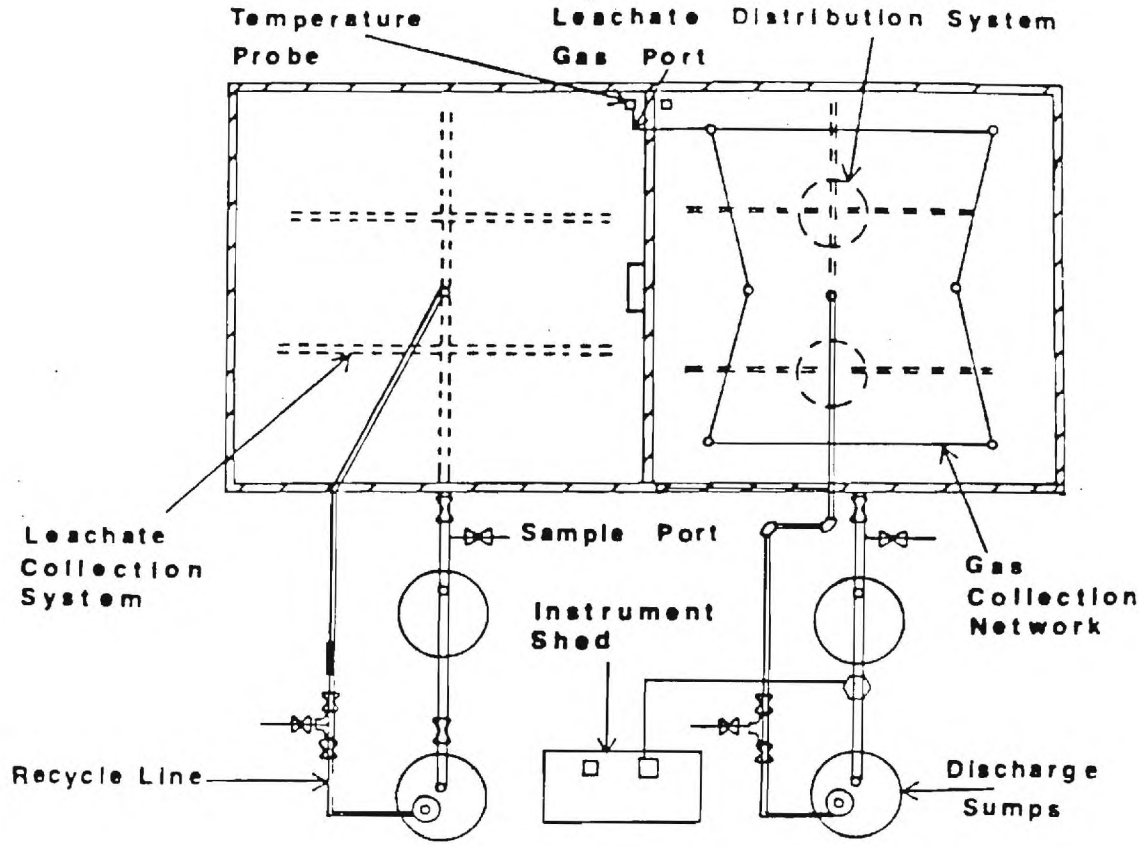
Each landfill cell received shredded and analyzed municipal solid waste compacted to depths of 2.74 m and 2.59 m, respectively, for the open and sealed cells and to a density of 319 kg/m^3. After about one year, apparent field capacity was reached followed by another seven months required to accumulate sufficient moisture to initiate daily leachate recycle. During this latter 208-day period, recycle was provided on a weekly basis and the routine analytical program was begun.

Leachate samples from both landfill cells were analyzed for: pH; oxidation-reduction potential; conductivity; total and individual volatile acids; total organic and inorganic (TOC and TIC) carbon; 5-day biochemical oxygen demand (BOD_5); chemical oxygen demand (COD); total, suspended and volatile solids; total alkalinity; nitrogen; phosphorus, sulfates; chlorides; and, selected metals (Fe, Ni, Mn, Cr, Cd, Mg, Cu, Na, K, Ca, Zn, Al, Pb). Gas samples were analyzed for CO_2, O_2, N_2, CH_4 and H_2. These analyses were supplemented by routine measurements of rainfall and ambient as well as internal cell temperatures. Preliminary analyses were also conducted for residual and/or refractory-type organic materials and for priority pollutants after accelerated stabilization of the readily available organic constituents in the leachate had been completed.

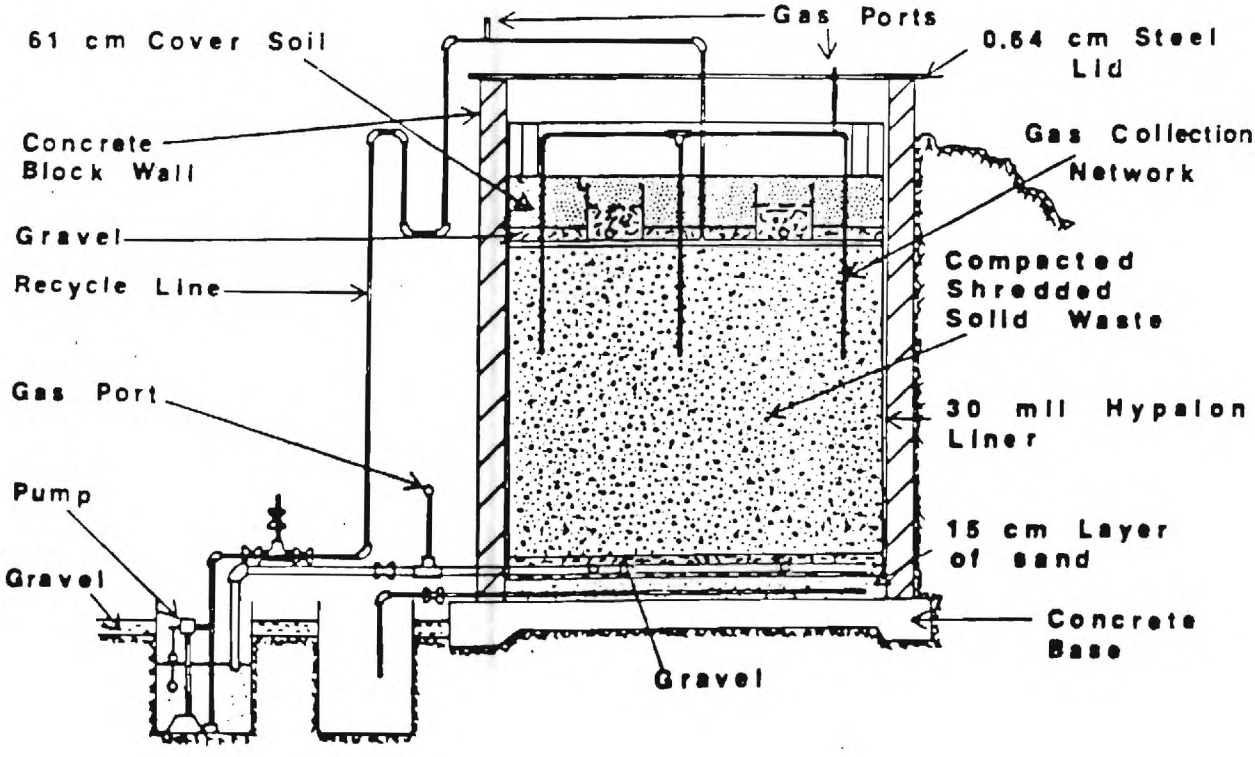
Experimental Results

The experimental results indicated that the use of shredded solid waste in combination with leachate recycle promoted a more immediate and complete settlement and consolidation of the waste into a relatively homogeneous mass and, although some impedence to flow was encountered, leachate recycle was sufficient to maintain adequate moisture and associated nutrient and substrate availability for accelerated stabilization to occur. The analytical data obtained during this period indicated reductions of leachate COD, TOC and BOD_5 concentrations of about 99% with even greater reduction being apparently precluded by eventual nutrient (phosphorus) deficiencies which developed toward the latter stages of the studies. Therefore, with nutrient sufficiency, microbial stabilization of the readily available organic fractions transferred from the solid waste to the leachate during leachate recycle was considered possible within a 6-month period after daily leachate recycle had commenced.

Accelerated stabilization progressed through acid and methane fermentation phases in a sequential manner and was enhanced by warmer temperature conditions. As volatile acids accumulated, pH decreased and corresponded to a buffer shift from that of the biocarbonate system to one characteristic of the acetate system. As volatile acids were converted to methane, a reversal of this trend



PLAN OF SIMULATED SANITARY LANDFILLS
(not to scale)



SECTION VIEW: SEALED CELL (not to scale)

Figure 1. Pilot-scale simulated landfill cells with leachate recycle.

occurred with the majority of the gas being produced over a relatively short 3-month period when environmental conditions favoring methane fermentation became optimum. A total of 7.1 m^3 of gas/1000 kg of dry waste (~3.7 m^3 CH_4/ 1000 kg) was produced during this period. Therefore, the predictability of gas production in terms of both magnitude and longevity of occurrence was enhanced by leachate recycle and associated accelerated waste stabilization.

Microbially mediated increases in volatile acid concentrations and concomitant decreases in pH tended to mobilize the heavy metals. Subsequent decreases in volatile acids and increases in pH, coupled with reducing conditions, resulted in their precipitation and filtration as metal sulfides. Preliminary analyses for aromatic hydroxyl groups suggested that complexing substances were present after accelerated stabilization which may have led to the eventual remobilization of selected heavy metals.

As with the metal sulfides, leachate recycle provided solids clarification mainly by filtration. Residual suspended solids concentrations averaged about 37 mg/l. These and other parametric analyses could be corrected for dilution and/or evaporation effects by employing chloride as a conservative tracer. Calculations indicated that Summer, Fall, Winter and Spring evaporation totaled 39%, 25%, 19% and 24% of the incident rainfall onto the open landfill cell, respectively.

Organic priority pollutant analyses on recycled leachate indicated the presence of each of the major classes, particularly the polynuclear aromatic hydrocarbons. Analyses on the cover soil provided some evidence that these latter pollutants were derived from outside sources, possibly through the mechanism of rainout. Therefore, these observations suggested that a variety of land disposal systems, including landfills, may be sensitive to the accumulation of priority pollutants generated in the vicinity and transported by meteorological events into these sites. However, continued rinsing of such contaminants through the site could be minimized by cupping and by removal of accumulated leachate after recycle had been terminated.

Economic comparisons with more common separate treatment of leachate by municipal activated sludge, aerated lagoons and anaerobic filters indicated that these systems were six to eight times more costly than treatment by leachate recycle. This reduction in cost, coupled with the other beneficial attributes of enhanced predictability and operational control, provides an impressive advantage over more traditional techniques of leachate management and treatment.

Conclusions

Collectively, the results of these research investigation have reaffirmed the advantages of leachate containment, collection and recycle in shortening the time during which gas and leachates with high pollutant concentrations are produced from a specific landfill cell. This reduction in time enhances the predictability of circumstances leading to the generation of both leachate and gas, thereby providing better opportunities for instituting safeguards against hazard and/or environmental impairment. The studies also served to augment the understanding of processes and attenuation mechanisms operative

within a landfill environment and to indicate areas in need of additional emphasis with regard to both research and applications in landfill disposal practice.

The full report was submitted in fulfillment of Grant No. R-803953 by the Georgia Institute of Technology under the sponsorship of the U. S. Environmental Protection Agency.